Endoscopic ultrasonographic evaluation of the esophagus in healthy dogs

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Objective—To characterize the ultrasonographic appearance of the canine esophagus.

Animals—14 healthy Beagles.

Procedures—Endoscopic ultrasonography (EUS) examinations were performed with a radial ultrasonographic gastrovideoscope in anesthetized dogs. Images were obtained at 3-cm intervals along the esophageal length to allow evaluation of the esophageal wall. Images were obtained with the probe in direct contact with the esophageal wall and with a water-filled balloon as a standoff.

Results—Images were obtained with (12 dogs) and without (10) the water-filled balloon. Median thickness of the esophageal wall was 2.19 mm (range, 1.03 to 5.62 mm) in the proximal third of the esophagus, 2.15 mm (range, 1.10 to 4.45 mm) in the middle third, and 2.84 mm (range, 1.35 to 5.92 mm) in the distal third. Wall thickness differed significantly between proximal and distal thirds. Results were similar when the water-filled balloon was used. Esophageal wall layers appeared as 5 alternating hyperechoic and hypoechoic bands that could not be consistently identified in all dogs. All layers could be identified in 26 of 198 (13%) images, 3 layers could be identified in 67 of 198 (34%) images, and 105 of 198 (53%) images had no layers. Visual identification of layers in images obtained with and without the balloon did not differ significantly.

Conclusions and Clinical Relevance—EUS appeared to be a useful technique for assessing esophageal wall integrity in dogs; however, complete evaluation of all layers could not be accomplished in all instances. Further studies with this technique in dogs are needed.

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Diseases of the esophageal wall can be challenging to diagnose via noninvasive methods. The diagnostic approach for esophageal disease is currently limited to radiography, esophagoscopy, and, less commonly, CT or MRI. Esophagoscopy allows the possibility of a full examination of the esophageal mucosal surfaces and enables clinicians to detect strictures, diverticula, intraluminal masses, or lodged foreign bodies as well as to obtain biopsy specimens. Although CT and in some instances radiography may be useful in detection of extraluminal and intraluminal esophageal disease, none of these modalities are capable of allowing evaluation of the architecture of the esophageal wall in as great a detail as does the use of ultrasonography because of the greater spatial resolution for ultrasonographic examinations. Although EUS and especially radial EUS are not readily available in clinical settings, this technique may have great potential for use in veterinary medicine, particularly for the diagnosis and understanding of esophageal disease. In clinical settings, a radiographically visible, partially fluid-filled mega-

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esophagus may hide esophageal masses and therefore be incorrectly interpreted as idiopathic megasopagus. Esophageal masses such as leiomyoma can be mistaken radiographically with granulomatous disorders, such as infestation with Spirocerca lupi. Another beneficial aspect of EUS might be its use in staging of mural esophageal disease, which facilitates planning for resection of esophageal tumors. A better diagnostic imaging tool is needed to provide a more sensitive and specific description of diseases of the esophagus.

Endoscopic ultrasonography has been used in human medicine to overcome limitations (eg, superimposition of other organs on radiographs or inadequate soft tissue contrast on CT images) encountered with other imaging modalities as well as limitations (eg, narrow intercostal spaces, lung-air interference, and obesity) encountered with transcostal and transabdominal ultrasonography. Assessment of the esophageal wall via EUS in humans has been described, and EUS is routinely used for staging of neoplastic diseases (eg, esophageal and gastric carcinomas) because it has better sensitivity than other imaging techniques.

Endoscopic ultrasonography has been used in small animals for evaluation of the gastric wall and other abdominal organs in situations requiring the need...
to overcome interference attributable to gas artifacts or extreme obesity. Furthermore, EUS has been used to investigate the mediastinum and selected intrathoracic lesions in dogs. Histologically, the canine esophagus is composed of the tunica adventitia, tunica muscularis (outer longitudinal and inner circular layer), submucosal glands, and mucosa; the mucosa is composed of 3 layers. The histologic appearance of the esophagus of dogs is similar to that of the esophagus in humans. Use of EUS in humans has revealed a 5-layer structure with alternating hyperechoic and hypoechoic layers, which is similar to the appearance of the intestinal wall of dogs. The histologic appearance of the esophagus of dogs is similar to that of the esophagus in humans. Use of EUS in humans has revealed a 5-layer structure with alternating hyperechoic and hypoechoic layers, which is similar to the appearance of the intestinal wall of dogs.

The tunica adventitia is evident as a thin hyperechoic layer, the tunica muscularis is evident as a hypoechoic layer, the submucosa is hyperechoic, and the mucosa is hypoechoic. The innermost layer, the mucosal surface, has been described as a thin hyperechoic line.

To the authors’ knowledge, the ultrasonographic appearance of the canine esophageal wall has not been described. Therefore, the objective of the study reported here was to assess the use of EUS for the evaluation of the esophageal wall architecture in healthy dogs and to compare the EUS results with histologic results.

**Materials and Methods**

**Animals**—Fourteen healthy Beagles (8 sexually intact females and 6 sexually intact males) with a median body weight of 13.4 kg (range, 10.9 to 15.7 kg) and a median age of 2 years (range, 1 to 5 years) were included in the study. The dogs were considered healthy on the basis of their medical history and results of a physical examination, CBC, serum biochemical analysis, and urinalysis. The study was approved by the Committee for the Permission of Animal Experimentation, Canton of Zurich, Zurich, Switzerland.

**Data collection**—Food was withheld from all dogs for a minimum of 16 hours before the EUS examination. All dogs were anesthetized for the EUS examination. Sedation was provided by IM administration of acepromazine maleate (0.03 mg/kg) and buprenorphine (0.014 mg/kg). Anesthesia was induced by administration of propofol and maintained with isoflurane (1.1% to 1.3% in oxygen).

Anesthetized dogs were positioned in left lateral recumbency, and the EUS examination was performed as described in another study. Images were obtained with an endoscopic processor, light source, and radial (360°) ultrasonographic gastrovideoscope (outer diameter, 13.8 mm; length, 1,250 mm) supported by an ultrasonographic unit. The ultrasonographic probe at the tip of the endoscope had a fundamental frequency of 5 to 10 MHz (Figure 1). Nonsterile balloons specially designed for the gastrovideoscope were attached over the transducer tip and could be filled with water and used as a standoff. Images were stored on the built-in hard disk of the ultrasonography machine and simultaneously transmitted to the image archiving and communication server of our hospital for further evaluation.

The ultrasonographic gastrovideoscope was initially placed orally into the cardia of the stomach and then gradually retracted cranially toward the pharynx. The cardia was not evaluated. Fluid or gas in the esophagus was evacuated with the gastrovideoscope’s suction device to prevent interference with imaging. The first image was obtained as soon as the esophagus was visible, and images were obtained at 3-cm intervals throughout the length of the esophagus (the first image was obtained immediately cranial to the cardia, and the last image was obtained immediately caudal to the pharynx). The procedure was repeated, and a set of images was obtained with the balloon expanded with water to act as a standoff. Balloon distention resulted in a distance of approximately 2 mm between the probe tip and esophageal wall.

**Evaluation of the wall thickness**—Measurements of the thickness of the esophageal wall and evaluation of the layers of the esophageal wall were performed on images obtained at 3-cm intervals. Measurements were obtained with the scale on the ultrasonography machine. Wall thickness was measured 3 times/image, and the mean value was calculated. Because of the length of the esophagus, 9 esophageal images were generally obtained. Thus, the length of the esophagus was divided into thirds, each of which encompassed approximately 9 cm, for subsequent analysis.

**Evaluation of the esophageal wall layers**—The thickness, layers, symmetry, and echogenicity of the esophageal wall were assessed and compared with data obtained via esophageal EUS in humans and with results of histologic examination in dogs. For optimal visualization of the esophagus, the ultrasonographic probe should be perpendicular to the esophageal wall.
Attempts were made to optimize the image during the procedure by changing the angle of the transducer tip gradually until a reasonably symmetric image of the entire esophageal wall was visible in cross section with the subjectively smallest and most consistent wall thickness.

**Statistical analysis**—Wall thickness was analyzed via a 1-way ANOVA with Bonferroni correction. Values of \( P < 0.05 \) were considered significant. Statistical analysis was performed with statistical software.

**Results**

**EUS images**—Images were acquired only with the water-filled balloon for the first 4 Beagles. At that time, the decision was made to change the procedures to compare images obtained with and without the water-filled balloon. In addition, images were obtained only without the water-filled balloon for 2 dogs (the balloon did not fill correctly for one dog, and the insufflation canal was blocked and thus the balloon could not be filled during the examination for the other dog). Therefore, images were obtained with the water-filled balloon for 12 dogs and without the water-filled balloon for 10 dogs.

**Esophageal wall thickness**—Thickness of the esophageal wall increased from oral to aboral. For images obtained without the water-filled balloon, median wall thickness was 2.19 mm (range, 1.03 to 5.62 mm) in the proximal third, 2.15 mm (range, 1.10 to 4.45 mm) in the middle third, and 2.84 mm (range, 1.35 to 3.92 mm) in the distal third of the esophagus (Figure 2). For images obtained without the water-filled balloon, median wall thickness was 2.05 mm (range, 1.05 to 3.83 mm) in the proximal third, 2.20 mm (range, 1.09 to 3.88 mm) in the middle third, and 2.61 mm (range, 1.11 to 5.12 mm) in the distal third of the esophagus. There was a significant \( (P < 0.001) \) difference in thickness between the proximal and distal third of the esophagus. The thickness measured in images obtained with the water-filled balloon was smaller (but did not differ significantly \( [P = 0.07] \)) from the thickness measured in images obtained without the water-filled balloon.

**Esophageal wall layers**—The esophageal wall did not consistently appear as 5 alternating hypoechoic and hyperechoic bands. Generally, there were 3 variations when assessing the identification of layers.

![Figure 2](image2.png)

**Figure 2**—Box-and-whisker plots of the thickness of the esophageal wall determined from images obtained without (n = 12 dogs; A) and with (10; B) a water-filled balloon used as a standoff in healthy Beagles. Numbers on the x-axis represent the position of the probe tip in the esophagus at which images were obtained. The images were obtained at 3-cm intervals; 1 represents the image obtained from the most distal portion of the esophagus immediately adjacent to the gastric cardia, and 9 represents the last image obtained in the most proximal portion of the esophagus immediately caudal to the pharynx. Each box represents the 25th to 75th percentiles, the horizontal line within each box represents the median, and the whiskers represent the minimum and maximum.

![Figure 3](image3.png)

**Figure 3**—Ultrasonographic images of the esophagus of representative Beagles with no evidence of wall layers (A), 3 visible wall layers (B), and 5 visible wall layers (C). The outer and inner limits of the esophageal wall are indicated (arrows). In panels B and C, notice the hypoechoic region (asterisk) for the water-filled balloon that served as a standoff. AC = Carotid artery. T = Trachea.
Variation 1 had no layers visible or the layers were ill-defined, variation 2 had 2 or 3 layers visible, and variation 3 had all 5 layers visible (Figure 3). There was no difference in the number of layers visible between images obtained with and without the water-filled balloon. In only 26 of 198 (13%) images were all 5 layers evident, but up to 3 layers could be identified in 67 of 198 (34%) images. There was no distinct evidence of layers in 105 of 198 (53%) images. Some differences existed among dogs. In 2 dogs, all layers were visible throughout the examinations with and without the water-filled balloon, whereas in 2 other dogs, layers were not detectable in any images. There was slightly better delineation of the layers in the proximal portion of the esophagus. However, values did not differ significantly among the portions of the esophagus.

Discussion

In the study reported here, we described the ultrasonographically detectable anatomy of the esophageal wall, including thickness and layers, via a 360° ultrasonographic gastroscope. Wall thickness and layers were assessed in images obtained with and without a fluid-filled balloon serving as a standoff. There was no significant difference in wall thickness between images obtained with and without the water-filled balloon. Furthermore, there was no effect of the water-filled balloon on the ability to identify layers of the esophageal wall.

A main finding was that the wall thickness increased from the proximal to the distal aspects of the esophagus. In humans, accuracy of measurements of the esophageal wall thickness can be affected by compressive effects of an inflated balloon standoff; increased filling of the balloon was associated with a decrease in wall thickness in 1 study.9 In that study,9 investigators made no effort to standardize the effect of balloon inflation. However, in the present study, we opted to fill the balloon in a consistent manner, which resulted in a distance of approximately 2 mm between the probe tip and esophageal wall. As expected, the thickness of the wall was slightly less in images obtained without the water-filled balloon, but this difference was not significant.

Textbooks differ in the information about the anatomic and histologic characteristics of the canine esophagus. In 1 anatomy textbook,17 the esophagus is divided into cervical, thoracic, and abdominal portions, and the mean thickness of the esophageal wall is approximately 4 mm in the cervical portion, 2.5 mm in the thoracic portion, and 6 mm in the area of the cardia. In the present study, the wall thickness increased significantly from the proximal third to the distal third of the esophagus. The obtained measurements reported here were consistently less than values reported for histologic examinations18; the explanation for this finding is the technical or chemical procedures used for histologic preparation of samples because tissue thickness increases with increasing duration of immersion in formalin. A limitation of the present study was the lack of a comparison in measurements between clinical and macroscopic postmortem preparation.

Unexpectedly, wall layers were not consistently seen in all dogs. Only 2 of 14 dogs had evidence of 5 layers throughout the entire esophagus. In the study reported here, esophageal wall layers were dependent on each dog. No association was evident between the number of wall layers and age, body weight, or sex. There also was great discrepancy in our ability to visualize the layers within specific dogs. This discrepancy is in contrast to the results of a study in humans10 in which all layers were evident throughout the entire esophagus in all examined individuals. The reason for this discrepancy cannot be explained.

Use of the water-filled balloon did not influence our ability to visually identify layers of the esophageal wall. It was believed that the water-filled balloon would increase the distance between the transducer and esophageal wall to avoid problems with near-field imaging. For optimal visualization of the wall, the probe should be perpendicular to the esophagus. However, the angle between the probe and esophageal wall cannot be fully assessed during EUS, although attempts were made to optimize the view during the examinations by changing the angle of the transducer tip to enable us to obtain a reasonably symmetric image of the esophagus in cross section. Artifacts attributable to gas interference were avoided by evacuating the luminal gas in the esophagus and by selecting images in which there were few or no reverberation artifacts. Because the thickness of the esophageal wall in dogs is comparable to that in humans, we do not believe that spatial resolution achieved with the ultrasonographic equipment was the reason for our inability to observe the esophageal wall layers in all dogs, although the near-field properties of the equipment we used were not compared with those of the equipment used by the investigators in that human study.9

On the basis of the findings in the present study, a reduction in the number of esophageal wall layers cannot be considered a sign of disease. This is in contrast to imaging of the gastrointestinal tract in dogs, whereby the number of layers in the intestinal wall can be used
as a sign of disease in dogs with neoplastic or granulomatous changes.\(^{18}\)

Although the layers were not visible in all images, assessment of the ultrasonographic architecture of the esophageal wall is possible with EUS. In contrast to a study\(^{9}\) in humans, we could not consistently identify all layers of the esophageal wall in all dogs. The increase in wall thickness from oral to aboral has to be accounted for when considering esophageal disease. To our knowledge, the study reported here is the first to provide information about the normal EUS appearance of the esophagus in Beagles. This information may serve as a reference for further studies in dogs, including those with esophageal disease.

a. Acepromacin, Fatro, Ozzano dell’ Emilia, Italy.
b. Temgesic, Reckitt Benckiser AG, Wallisellen, Switzerland.
c. Propofol 1%, Fresenius, Stans, Switzerland.
d. Iso Flo, Dr. E. Graeub AG, Bern, Switzerland.
e. Olympus UE-160 AL-5, Olympus Switzerland AG, Volketswil, Switzerland.
f. Aloka Prosound alpha 10, Hitachi Medical Systems Europe Holding AG, Zug, Switzerland.

References