Quantitative Ultrasonography of the Stomach and Small Intestine in Healthy Dogs

Roman A. Tcygansky\textsuperscript{1}, Irina I. Nekrasova\textsuperscript{2}, Angelina N. Shulunova\textsuperscript{3}, Alexander I. Sidelnikov\textsuperscript{4}

\textsuperscript{1,2,3,4}Federal State Budgetary Educational Institution of Higher Education «Stavropol State Agrarian University»

gypsyrom@mail.ru, irine_nekrasova@mail.ru, linok9@mail.ru, alsid153@mail.ru

Corresponding Author: Roman A. Tcygansky

\url{https://doi.org/10.26782/jmcms.spl.10/2020.06.00045}

Abstract

\textbf{Purpose.} To determine the quantitative echogenicity indicators (and their ratio) of the layers of stomach and small intestine wall in healthy dogs.

\textbf{Methods.} A prospective 3-year study of 86 healthy dogs (aged 1-7 yrs) of different breeds and of both sexes. Echo homogeneity and echogenicity of the stomach and intestines wall were determined by the method of Silina, T.L., et al. (2010) in absolute values of average brightness levels of ultrasound image pixels using the 8-bit scale with 256 shades of gray.

\textbf{Results.} Quantitative echogenicity indicators of the stomach and the small intestine wall in dogs were determined. Based on the numerical values characterizing echogenicity distribution in each layer of a separate structure of the digestive system, the coefficient of gastric echogenicity is determined as 1:2.4:1.1 (mucosa/submucosa/muscle layers, respectively), the coefficient of duodenum and jejunum echogenicity is determined as 1:3.5:2 and that of ileum is 1:1.8:1.

\textbf{Clinical significance.} The echogenicity coefficient of the wall of the digestive system allows an objective assessment of the stomach and intestines wall and can serve as the basis for a quantitative assessment of echogenicity changes for various pathologies of the digestive system.

\textbf{Keywords:} Ultrasound (US), echogenicity, echogenicity coefficient, digestive system, dogs, stomach, intestines

I. Introduction

Ultrasound investigation (US) as a routine method of visual diagnosis has been used in various fields of veterinary medicine: cardiology, obstetrics, urology, endocrinology, orthopedics, gastroenterology, and other digestive
system examinations in veterinary practice for more than 27 years [XXII]. This method is non-invasive and does not require food deprivation of the patient before the study [VII].

Transabdominal ultrasonography is a practical tool for assessing the thickness and integrity of the intestinal wall in small animal veterinary medicine. Thus, Günther, C.S. et al. (2014) made a correlation analysis of 3600 measurements of the wall thickness of each intestinal segment performed by two ultrasound specialists on transverse ultrasonographic images in 30 healthy dogs and found a significant positive correlation (p <0.01) of the measurement data obtained by different specialists, as well as good reproducibility of repeated measurements [XIII].

The topographic and morphometric characteristics of the structures of the digestive system in healthy dogs are discussed in the works by Delaney, F. et al. (2003), Gladwin, N.E. et al. (2014), Gory, G. et al. (2014) and others establishing quantitative thickness characteristics of various sections of the digestive system [IV, XI, XII].

It has been established that the digestive system of dogs has five characteristic echographic layers corresponding to the outer part of the lumen and the border of the lumen with the mucosa, submucosa, muscle and serous membrane [I, XII, XXI].

Ultrasound allows studying not only the structure but also the function of the digestive system. Thus, Choi, M., et al. (2002) studied the motility of the pyloric stomach and the time of gastric emptying using ultrasound (the zone and volume method). The authors concluded it is easier to determine the time of emptying by the zone method, yet the volume method is more accurate [III]. Recently, in the practice of veterinary visual diagnostics, echo-contrast preparations have been used which contribute to the amplification of the ultrasonic signal. A study by Diana A. et al. (2011) established some parameters of the small intestine perfusion, the time of contrast and the time of its outflow in cats [V].

US detection of intestinal segments with visualization of wall layers and registration of peristalsis can be used to assess intestinal development, which allows reliably determining the end of embryonic organogenesis in dogs [X].

An important parameter in ultrasonography is the echogenicity of the studied structure [II]. The vast majority of works devoted to the analysis of changes detected by US are based on the subjective and unproven perception of the main ultrasonic criterion - echogenicity, and quantitative assessment is carried out only by counting subjectively evaluated iso-, hypo- or hyperechoic ultrasound structures.

Thus, it is indicated that the mucosa and muscle layer of the intestine are hypoechoic, and the border of the intestine lumen with the mucosa, submucosa and serous membranes is hyperechoic [XX], yet there is no evidence of echo homogeneity and the degree of severity of echogenicity in a certain section of the digestive system.

A significant number of publications are based on the characteristic of echogenicity. Le Roux A. B., et al. (2016) observed dual echogenicity of the mucosa in addition to the five established layers. Histologically, this double echogenicity was characteristic.
of intestinal villi (moderately echogenic) and of the lamina propria (hypoechoic) [XVIII].

Heng H.G. et al. (2015) described the hyperechoic band in the muscle layer of the colon of healthy dogs, located parallel to the serous layer and distributed focally, diffusely or combined. Histologically, this band is identified as fibrous tissue. The authors concluded that the detectable structure in the colon of dogs might be a variant of the norm, and not a marker of the disease [XV].

Pollard R.E. et al. (2013) observed an increase in the echogenicity of the mucosa of the small intestine after oral administration of corn oil in all the five examined healthy dogs. Mucosal echogenicity was subjectively evaluated visually. The authors recorded parallel hyperechoic lines of the jejunum mucosa in four out of five dogs [XXIV].

The work by RaultD.N., et al. (2004) is devoted to the identification of the echogenic band recorded in the ultrasound image of the intestinal loop in cross section passing through the mucosa on both sides of the loop. The studies were carried out in vivo and in vitro with polyposition scanning. The band was present only when the loop was flat. Histologically, a greater distance between the villi in this section of the mucosa was established. The authors concluded that the echogenic strip of the intestinal mucosa is an interface inside the mucous membrane due to the changed position of the villi on both sides of the intestinal wall in the folded segment of the intestine with a maximum cross section [XXV].

Gaschen L. et al. (2016) investigated the echogenicity of the small intestine mucosa in 60 healthy dogs after a diet with the recommended amount of fat and 1.5 ml/kg of corn oil added to the diet. An increase in the echogenicity of the mucosa immediately after eating more fatty foods and 60 minutes after taking both diets was noted, and significantly higher echogenicity was in the group of dogs with a fatty diet. However, Granger L.A. et al. carried out an assessment of echogenicity for the jejunum and duodenum mucosa visually at points 0-1-2, where 0 is anechoic mucosa, 1 is a small number of light specks present, 2 is a large concentration of specks. The authors concluded that echogenicity of the intestinal mucosa can be increased in healthy dogs after eating, regardless of the fat content in the diet [VIII].

There are some reports of compared quantitative characteristics of the echogenicity of a number of structures. A study by Ivančić M. et al. (2008) compares the echogenicity of the liver parenchyma and kidney cortex in healthy dogs. Echogenicity was determined using digital image analysis in Image J 1.38d, Wayne Rasband, U.S. National Institutes of Health, Bethesda, MD in average pixel intensity using the 8-bit scale with 256 shades of gray. The authors concluded that the echogenicity of the renal cortex is higher than that of the liver in different scan modes. Earlier, isoechogenicity of these structures based on subjective perception was allowed [XVI].

The lack of information in the available foreign literature on the quantitative characterization and ratio of echogenicity of the intestinal layers in dogs served as the
basis for the present research. The Russian literature does not cover US diagnostics of the digestive system in dogs.

**Research objectives:** to quantify the echogenicity and the ratio of the stomach and small intestines wall layers in dogs and to determine the echogenicity coefficient of the intestine.

**II. Material and Methods**

The object of the study was healthy dogs of different breeds and of both sexes. The research was conducted at Pirogov Veterinary Center, Stavropol, from August 2014 to September 2017. 86 dogs aged 1-7 years were examined. Ultrasound was performed on a SIUI Apogee 1100 Omni scanner (Shantou Institute of Ultrasonic Instruments Co., Ltd., Guangdong, China) according to the generally accepted method using a multi-frequency linear sensor with the frequency of 5-13 MHz. Animals were examined in dorsal, left and right lateral lying position. The study was conducted in the modes of two-dimensional seroscale imaging (B-mode).

Echogenicity of the stomach wall layers was investigated in the fundus which was studied in the xiphoid process. The duodenum was scanned on the right, starting from the space between 9-10 ribs moving the sensor in the caudal direction along the right side of the body. Visualizing the cranial part of the duodenum in the pylorus and the cranial curve, the sensor was advanced in the caudal direction; the descending part, the caudal curve, the transverse and ascending part of the duodenum were determined. Echogenicity of the duodenum wall layers was investigated in the descending part, behind the cranial curve. The remaining sections of the small intestine were evaluated by moving the sensor from right to left and left to right, and then in the cranial-caudal direction, visualizing the small intestine along the entire length. Slices of the jejunum were examined depending on the relative position of the sensor and the intestine, in the sagittal plane, in the transverse plane, as well as in a number of lateral projections. The ileum was examined in the right mid-cranial parts of the abdominal cavity and identified by its connection with the ascending colon and cecum. Echogenicity of the ileum was evaluated at a distance of 4-5 cm from the junction with the ascending colon.

Homoechogenicity and echogenicity of the stomach and small intestine wall layers were determined according to the method of Silina T.L. et al. (2010) [II]. To assess the homoechogenicity, two zones (the studied and the background) of the same layer located at the same distance from the sensor were compared. An ultrasound image of the intestine was analyzed on an IBM PC-compatible computer in Adobe Photoshop photo editor in black and white (triple scale); for this, after switching on the histogram function, the studied zone and the background zone were selected with the lasso tool. In this case, the numerical values of the parameters ‘average value’ and ‘deviation’ were displayed automatically in the histogram window of Adobe Photoshop. For the background zone, the ‘deviation error in the background zone’ was also determined; for this, the background zone was divided into several sections, determining the deviation value in each; the maximum deviation and minimum
deviation in the background zone or in its sections were selected. Next, the deviation error in the background zone was calculated according to the formula:

\[ E_{Dev2} = Dev_{add\ max} - Dev_{add\ min}, \]

where

\[ E_{Dev2} \] – is the deviation error in the compared zone;

\[ Dev_{add\ max} \] – is the maximum deviation value in the compared zone or its sections;

\[ Dev_{add\ min} \] – is the minimum deviation value in the compared zone or its sections.

Then, the difference between the deviations in the studied and the background zones was calculated by the formula:

\[ \Delta Dev = Dev_1 - Dev_2, \]

where

\[ \Delta Dev \] – is the deviations difference between the studied and the compared zone;

\[ Dev_1 \] – is the deviation in the studied zone;

\[ Dev_2 \] – is the deviation in the compared zone.

The deviations in the background zone were compared with the deviations difference in the studied and the background zones according to the formula:

\[ HC = E_{Dev2} - \Delta Dev, \]

where

\[ HC \] – is the homoechogenicity criterion of the studied zone;

\[ E_{Dev2} \] – is the deviation error in the compared zone;

\[ \Delta Dev \] is the deviations difference between the studied and the compared zones.

Next, the difference between the arithmetic mean values of the brightness of the studied and background zones were calculated according to the formula:

\[ \Delta Av_{br} = Av_{br1} - Av_{br2}, \]

where

\[ \Delta Av_{br} \] – is the difference in average brightness values;

\[ Av_{br1} \] – the average brightness value in the studied zone;

\[ Av_{br2} \] – the average brightness value in the background zone.

Next, the module of the average brightness difference of the homoechoic studied zone and the average brightness of the background zone with a deviation in the background zone were compared according to the formula:

\[ IC = |\Delta Av_{br}| \cdot Dev_2, \]

where

\[ IC \] – is the isoechogenicity criterion of the studied zone;

\[ |\Delta Av_{br}| \] – is the module of the difference in average brightness values;

\[ Dev_2 \] – is the deviation in the compared zone.

With these calculations, the degree of homoechogenicity of the layers was determined. The homoechogenicity of a particular layer determined its echogenicity.
The studied zone was defined as heteroechoic if EC was <0; isoechoic if EC was 0 ≤ HC, IC ≤ 0; hypoechoic if EC was 0 ≤ HC, 0 < IC, ΔAvbr < 0; hyperechoic if EC was 0 ≤ HC, 0 < IC, 0 < ΔAvbr. Then, the ratio of the quantitative units of echogenicity of the muscle, submucosa and mucosa of different parts of the small intestine was determined, and the coefficient or index of intestinal echogenicity was calculated.

Numerical data were processed using univariate analysis of variance and Student's t-test for multiple comparisons; the dependence was revealed during the correlation analysis by calculating the linear Pearson coefficient in Primer of Biostatistics 4.03 for Windows on an IBM PC-compatible computer.

III. Results

The stomach in the transverse scan is visualized as an oval or round structure, with folds are located radially in the form of finger-shaped outgrowths oriented inwards the cavity. In the longitudinal scan, the stomach wall folds are visualized as horizontally oriented lines with alternating submucosa and mucosa.

Directly behind the pyloric sphincter of the stomach, the cranial part of the duodenum is visualized represented by the ampoule of the duodenum. It is characterized by a significantly developed submucosa and a less developed mucosa.

In the caudal direction, the descending part of the duodenum adjacent to the right lateral and medial lobes of the liver, then to the parietal peritoneum of the dorsolateral abdominal wall is visualized. Approximately at the level of 5-6 lumbar vertebra, the caudal curve, the short transverse part and the ascending part of the duodenum can be visualized. Then it passes into the jejunum, medially oriented in the abdominal cavity.

The ileum can visually be differentiated by a less pronounced mucosa and by its connection with the ascending colon in the right mid-cranial portions of the abdominal cavity.

When calculating the homogeneity of each individual layer of the intestinal wall, the authors of the present research found that the stomach and small intestine wall layers in healthy dogs (with the exception of the ileum mucosa) are homoechoic, since the HC was positive (> 0) and the IC did not exceed 0. The mucosa and muscle layers are hypoechoic, since the relative criteria for the submucosa correspond to the position: 0 ≤ HC, 0 < IC, ΔAvbr < 0. The echogenicity of the duodenum and jejunum mucosa is almost the same (Table 1). The echogenicity index of the gastric mucosa (average brightness) is 29.15% higher than that of the duodenum and jejunum mucosa, and the echogenicity of the ileum mucosa is 2 times higher than that of the duodenum and jejunum mucosa. The submucosa and serous layers are hyperechoic, since the calculated criteria for the mucosa correspond to the position: 0 ≤ HC, 0 < IC, 0 < ΔAvbr. Echogenicity values of the stomach, duodenum, jejunum and ileum submucosa have similar meanings, with no significant differences. However, the quantitative echogenicity indicator of the stomach submucosa (average brightness) is 6.5% lower than that of the duodenum and jejunum submucosa and 13.2% lower than that of the ileum submucosa.
The echogenicity of the muscle layer is almost the same in different parts of the small intestine of dogs (Table 1), yet this figure is lower in the stomach wall by 21.45%.

**Table 1:** Quantitative echogenicity indicators of the wall of the digestive system structures in dogs (n = 86)

<table>
<thead>
<tr>
<th>Digestive system section</th>
<th>Wall layers</th>
<th>Average pixel brightness</th>
<th>Pixel brightness values range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>M±m</td>
<td></td>
</tr>
<tr>
<td>Stomach</td>
<td>mucosa</td>
<td>56.46±15.62</td>
<td>10.32±1.63</td>
</tr>
<tr>
<td></td>
<td>submucosa</td>
<td>134.9±18.75*/##</td>
<td>13.75±3.49</td>
</tr>
<tr>
<td></td>
<td>muscle</td>
<td>68.1±18.9</td>
<td>12.29±2.1</td>
</tr>
<tr>
<td>Duodenum</td>
<td>mucosa</td>
<td>40.48±5.98</td>
<td>10.28±1.67</td>
</tr>
<tr>
<td></td>
<td>submucosa</td>
<td>144.5±11.02*/##</td>
<td>19.73±3.14</td>
</tr>
<tr>
<td></td>
<td>muscle</td>
<td>86.44±16.64 **</td>
<td>15.97±2.75</td>
</tr>
<tr>
<td>Jejunum</td>
<td>mucosa</td>
<td>39.55±7.54</td>
<td>8.04±2.23</td>
</tr>
<tr>
<td></td>
<td>submucosa</td>
<td>142.9±15.75*/##</td>
<td>13.16±2.84</td>
</tr>
<tr>
<td></td>
<td>muscle</td>
<td>89.46±14.01*</td>
<td>10.98±2.55</td>
</tr>
<tr>
<td>Ileum</td>
<td>mucosa</td>
<td>83.25±13.57</td>
<td>12.89±3.55</td>
</tr>
<tr>
<td></td>
<td>submucosa</td>
<td>152.68±16.74*/#</td>
<td>15.8±3.97</td>
</tr>
<tr>
<td></td>
<td>muscle</td>
<td>84.17±12.52</td>
<td>12.34±3.11</td>
</tr>
</tbody>
</table>

Note: * is the significant difference with the mucosa (p≤0.01)
** is the significant difference with the mucosa (p≤0.05)
# is the significant difference with the muscle layer (p≤0.05)
## is the significant difference with the muscle layer (p≤0.05)

Since the quantitative echogenicity indicators of the wall layers of various digestive system sections have significant differences, the authors of the present research determined the ratio of the quantitative echogenicity units of the muscle layer, submucosa and mucosa of different sections of the small intestine.
Thus, in the stomach, the average brightness ratio of the mucosa/submucosa is 2.38 ± 0.31; that of the mucosa/muscle layer is 1.14 ± 0.26; that of the submucosa/muscle layer is 1.97 ± 0.20. In the duodenum, the average brightness ratio of the mucosa/submucosa is 3.55 ± 0.26; that of the mucosa/muscle layer is 2.11 ± 0.17; that of the submucosa/muscle layer is 1.65 ± 0.12. Similar ratios were obtained when analyzing the jejunum. In the ileum, the average brightness ratio of the mucosa/submucosa is 1.83 ± 0.14; that of the mucosa/muscle layer is 1.02 ± 0.11; that of the submucosa/muscle layer is 1.8 ± 0.15.

Based on these calculations, the echogenicity coefficients of the stomach and small intestine wall in dogs were determined:

- 1:2.4:1.1 (mucosa/submucosa/muscle layers, respectively) for the stomach;
- 1:3.5:2 for the duodenum and jejunum,
- 1:1.8:1 for the ileum.

Taking the echogenicity of all the layers as 100%, the authors calculated the proportion of each layer echogenicity. Then, the echogenicity percentage is distributed in layers as follows:

- the stomach wall 21.76% (mucosa), 51.99% (submucosa), 26.25% (muscle) (Figure 1);
- the duodenum wall 14.91%, 53.24%, 31.85% (Figure 2);
- the jejunum wall 14.54%, 52.55%, 32.9% (Figure 3);
- the ileum wall 26.01%, 47.7%, 26.29% (Figure 4).

![Fig. 1](image)

**Fig. 1**: Echogenicity of the mucosa, submucosa and muscle layers in the total echogenicity of the stomach wall (excluding the serous layer) in healthy dogs (n = 86).
Characterizing the echogenicity of each layer of the studied part of the digestive system as a percentage of the maximum echo signal reflection expressed as the maximum pixel brightness of the 8-bit image equal to 256, the following results were obtained:

**Fig. 2:** Echogenicity of the mucosa, submucosa and muscle layers in the total echogenicity of the duodenum wall (excluding the serous layer) in healthy dogs (n = 86).

**Fig. 3:** Echogenicity of the mucosa, submucosa and muscle layers in the total echogenicity of the jejunum wall (excluding the serous layer) in healthy dogs (n = 86).

**Fig. 4:** Echogenicity of the mucosa, submucosa and muscle layers in the total echogenicity of the ileum wall (excluding the serous layer) in healthy dogs (n = 86).
obtained: the stomach – 22.05% (mucosa), 52.69% (submucosa), 26.6% (muscle); the duodenum – 15.51%, 56.44%, 33.76%; the jejunum – 15.45%, 55.82%, 34.94%; the ileum – 32.52%, 59.64%, 32.88% (Figure 5).

Fig. 5: Echogenicity of the mucosa, submucosa and muscle layers of the stomach and small intestine wall as a percentage of the maximum possible value of the reflected echo signal in healthy dogs (n = 86).

IV. Discussion

The dogs’ digestive system is represented on sonograms by horizontally oriented linear structures during longitudinal scanning and rounded structures with radial layer orientation during transverse scanning with a clear differentiation of layers echogenicity. US scanning allows differentiating all the layers of the stomach and small intestine wall: mucosa, submucosa, muscle, serous.

As known, the basic principle of US is to compare the image of one tissue (region) under study with that of another, i.e. echogenicity characteristic of a particular body structure. In the main scanning mode – (B-mode, from the English word ‘brightness’), the US image is evaluated on a gray scale formed by the scanner based on the interaction of ultrasound with body tissues. At the same time, objects with different brightness levels are visualized on the monitor. Since brightness is a subjective attribute of the perception of an object’s properties, the analysis of changes detected by ultrasound based only on visualization can have a different interpretation. The standard 8-bit image contains 256 different brightness levels; a tool for its analysis is a brightness histogram which is a gradient diagram of brightness from zero (absolutely dim, black) to 255 (absolutely bright, white); vertically, the number of image pixels that have the corresponding brightness is shown.

When analyzing the echogenicity of the wall layers in the dogs’ digestive system, the authors obtained the average brightness quantitative indicator, which is a weighted average brightness level of image pixels, automatically calculated on the computer by multiplying each brightness level by the number of pixels of a given level, and then dividing by the total number of brightness levels. When characterizing the intestinal wall echogenicity, it is important to obtain information about the homoechogenicity of the studied zone by comparing the range on the gray scale inside the study zone.
and the compared zone. If this range in the studied zone is not greater than in the compared zone, the study zone is considered homoechoic. If it is greater, then the studied zone is heteroechoic. However, if homoechogenicity of different sections (not the entire zone) is determined in the compared zone itself, the deviation values for each section may differ slightly from each other. This may depend on the properties of the zone itself and on the resolution of the ultrasound scanner. The determination of the maximum and minimum deviations in the compared zone with the difference in values is the ‘deviation error in the compared zone’. This parameter is necessary since the deviation of the studied zone can slightly exceed the deviation in the compared zone, and if this excess is within the deviation error in the compared zone, the studied zone will be homoechoic. Heteroechoic zones cannot differentiate according to the degree of echogenicity. Homoechoic studied zones must be differentiated into isoechoic, hypoechoic and hyperechoic: if the studied zone does not differ from the compared zone more than various points in the compared zone differ from each other, the studied zone is comparable in echogenicity with the compared zone, i.e. the studied zone is isoechoic; if this difference is larger, the studied zone is either hypoechoic (decreased echogenicity) or hyperechoic (increased echogenicity).

The present research confirms that the stomach and small intestine mucosa is hypoechoic, which is also confirmed by Penninck D.G. et al. (2008) [XXI] and Agut A. (2009) [I]. However, the echogenicity of this layer in the stomach was 29.15% higher than in the duodenum and jejunum. This difference may be due to the predominance of villi and crypts in the lamina propria of the duodenum and jejunum mucosa. The significant difference in the ileum mucosa echogenicity with the rest of the small intestine can be explained by the heterogeneity of this layer which the authors recorded in 54 dogs, 62.79% of the examined animals. The authors of the present research believe this is due to the lymphoid tissue in the wall of this section, which is confirmed by the data of other researchers [XVIII].

The submucosa is hyperechoic, and the muscle layer is hypoechoic in all the studied sections. In the small intestine, these indicators are comparable, and their lower values in the stomach wall are possibly due to the peculiarities of the blood supply to this section of the digestive system.

Le Roux A. B., et al. (2016) observed dual echogenicity of the mucosa. Histologically, this double echogenicity was characteristic of intestinal villi (moderately echogenic) and the lamina propria (hypoechoic). However, the authors described this on ex vivo intestinal fragments placed into agar in a water container. In in vivo studies, the authors of the present research did not observe such heterogeneity [XVIII].

Changes in the intestinal wall echogenicity may be a variant of the norm. Nielsen T. et al. (2015) found an asymmetrically located hypoechoic extra layer (1.0 mm thick) in the submucosa of the distal jejunum and ileum in 20 cats aged 6-18 months using high-frequency ultrasound (18 MHz). Histologically, the authors found this layer is normal lymphoid tissue (Peyer's plaques) in the lamina propria of the mucosa and
submucosa. Besides, the authors found a similar layer in the proximal direction in the jejunum in 10 (50%) cats [XIX].

In addition, a change in the echogenicity of the digestive system structures can be a sign of pathologies. Sutherland-Smith J. et al. (2007) examined 23 dogs with sonographically detectable diffuse (70%) or multifocal (30%) hyperechoic mucosa bands of the small intestine followed by a biopsy of the intestinal wall obtained endoscopically or during laparotomy. In 96% of dogs, inflammation and dilatation of the lymphatic vessels of the mucosa were histologically established [XXVI]. Hanazono, K. et al. (2012) compared the clinically significant US signs of gastrointestinal stromal tumors in dogs with the actual frequency of metastasis and the detection of malignant neoplasms obtained by postoperative pathological examination. The authors expressed the possibility of determining the metastasis potential of a dog’s gastrointestinal stromal tumor before surgery using ultrasound, taking into account characteristic features, in particular, heterogeneous internal echogenicity with large hypoechoic regions [XIV]. The hyperechoic band in the intestinal mucosa parallel to the submucosa corresponded to the histopathological diagnosis of mucosal fibrosis in cats [XXIII].

For some pathologies, the diagnostic value of US is undeniable. For instance, ultrasonography allows accurately diagnosing intestinal invagination and is a useful method to search for concomitant or predisposing lesions [XVII]. However, diagnostic errors are possible when interpreting ultrasound images. Garcia, D.A.A. and Froes, T.R. (2012) compared 105 ultrasound diagnoses in 88 dogs and 17 cats with the results of a surgical study to identify and classify potential diagnostic errors. Any diagnostic errors made by the sonographer were classified as perceptual, cognitive, equipment related, inevitable or multifactorial. Errors were found in US diagnostics in 17 animals (16.2%), identifying them as cognitive (10 animals), inevitable (5 animals) and multifactorial (2 animals). The authors believe that understanding the causes of these errors will contribute to the improvement of this visualization method [VI].

There are reports that echogenicity of the mucosa may be a better parameter for detecting inflammatory bowel disease than the intestinal wall thickness in dogs with chronic diarrhea [IX].

The echogenicity coefficient of the stomach (1:2.4:1.1 in mucosa/submucosa/muscle layers, respectively), of the duodenum and jejunum (1:3.5:2) and the ileum (1:1.8:1) provides information on the ratio of quantitative echogenicity indicators of the intestinal wall in dogs. The settings of the scanner itself can affect these indicators; however, this coefficient allows an objective assessment of the intestinal wall, taking into account the variability of scanners settings.

V. Conclusion

The obtained absolute echogenicity values of the wall layers in healthy dogs’ digestive system structures, expressed in quantitative terms of the weighted average brightness levels of the US image pixels, allowed determining their ratio in the

Roman A. Tsygansky et al
stomach, duodenum, jejunum and ileum. Numerical values were also obtained that characterize the echogenicity distribution in each layer of a separate structure of the digestive canal as a percentage of the maximum reflection of the echo signal, expressed as the maximum pixels brightness of the 8-bit image equal to 256. These indicators can serve as a basis for the quantitative assessment of echogenicity changes in various pathologies of the digestive system.

The authors of the present research analyzed the sonograms of the stomach and intestines in healthy dogs on an IBM PC-compatible computer using Adobe Photoshop in black and white, which limits the effective practical application of these measurements. Numerous ultrasound scanners contain a luminance histogram in additional options which allows determining the echogenicity of an individual structure directly on the scanner monitor; however, to calculate the echogenicity coefficient, it is necessary to transfer data to a computer. In the future, a quantitative determination of the echogenicity coefficient of the stomach or intestines wall will be possible due to the integration of the corresponding formulas into the scanner software.

Along with the numerical measurement of wall and individual layers thickness, it will be possible to obtain numerical echogenicity values of the layers, compare their ratio with the established parameters in healthy animals and draw a conclusion based not on the subjective perception of this value but on objective numerical parameters. This will help improve the US diagnostic method; however, the quantitative characterization of the echogenicity of the digestive system structures in case of various pathologies requires additional studies.

References


II. Bull. 4. RF patent 2398513, IPC51A61B8 / 00 A61B8 / 14 (2006.01) A method for determining the homoechogeneity and the degree of echogenicity of an ultrasound image / T. Silina, S. S. Golubkov. - No. 2008149311/14; declared 12/16/2008; publ. 09/10/2010


IX. Gaschen, L., Kircher, P., Stussi, A., Allenspach, K., Gaschen, F., Doherr, M., Grone, A. Comparison of ultrasonographic findings with clinical activity index (CIBDAl) and diagnosis in dogs with chronic enteropathies // Veterinary radiology and ultrasound. – 2008. – Vol. 49. – № 1. – P. 56-64.


Roman A. Tcygansky et al


Roman A. Tcygansky et al

732