Dogs and cat’s jejunum echoicity characterization in the postprandial period

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Abstract. The article is devoted to the quantitative characterization of dogs and cats’ jejunum mucus membrane echoicity in different functional states (fasting and postprandial period). The object of the study was healthy dogs of different ages and different breeds (17) and cats (14) of both sexes at the age from 1 to 7 years. The studies were carried out at the Pirogov Veterinary Center in Stavropol using a SIUI Apogee 1100 Omni scanner (Shantou Institute of Ultrasonic Instruments Co., Ltd., Guangdong, China) according to the standard technique using a multi-frequency linear sensor with a frequency of 7-12 MHz. Echohomogeticity and echoicity of the intestinal wall was determined by the method of Silina T L, et al. (2010). Animals were examined before feeding with a preliminary 10-12 hour fasting diet, 20, 40, 60, 90, 120 and 180 minutes after feeding with Purina® ready-made dry food. Mucous membrane echoicity of dogs and cats’ duodenum and jejunum does not change after feeding however 64.7% of dogs had single and multiple small inclusions and less often a longitudinal hyperechoic stripe appears in the mucosa. These changes are most expressed from 60 to 120 minutes after feeding and mostly disappear by 180 minutes. Only 21.4% of cats showed the presence of single hyperechoic inclusions in the mucous membrane of the duodenum or jejunum from 40 to 90 minutes after feeding. The described changes in the mucous membrane of the jejunum must be taken into account when an ultrasound scan is performed on an animal after a meal.

1. Introduction
Ultrasound examination (US) as a non-invasive method of visual diagnostics in veterinary gastroenterology has been used for more than 30 years [1]. One of the important parameters in ultrasonography is the structure’s echoicity under study [2]. The overwhelming majority of works devoted to the analysis of changes detected during ultrasound examination are based on subjective, unproven perception of the main ultrasound criterion – echoicity and quantitative assessment is made only by counting subjectively assessed iso-, hypo- or hyperechoic ultrasound structures. Thus, it is indicated that the bowel’s mucous and muscular layers are hypoechoic and the border of the bowel lumen with the mucous membrane, the submucosa and serous membrane are hyperechoic [3] but there is no information about echo-uniformity and the degree of echoicity in one or another section of the alimentary track.

Pollard R E et al. (2013) observed an increase in the echoicity of the mucous membrane of the jejunum after oral administration of corn oil in all five examined healthy dogs. Echoicity of the mucosa was assessed visually subjectively. The authors recorded parallel hyperechoic mucosal lines in the jejunum among four dogs out of five [4]. Gaschen L et al. (2016) investigated the echoicity of the mucous membrane of the jejunum among 60 healthy dogs after feeding a diet with the recommended...
amount of fat and adding 1.5 ml / kg of corn oil to the diet. An increase in the echoicity of the mucous membrane was noted immediately after the intake of more fatty foods and 60 minutes after the intake of both diets. The authors concluded that the echoicity of the bowel mucosa could be increased among healthy dogs after a meal regardless of dietary fat content. However, the assessment of echoicity for the mucous membrane of the jejunum and duodenum the authors carried out visually in points 0-1-2, where 0 - anechoic mucosa, 1 - few light mottings, 2 - high concentration of mottings [5].

Sutherland-Smith J. et al. (2007) studied 23 dogs with sonographically detectable diffuse (70%) or multifocal (30%) hyperechoic bands of the jejunum mucosa followed by biopsy of the intestinal wall obtained endoscopically or during laparotomy. 96% of dogs had inflammation and dilation of mucosal lymphatic vessels histologically established [6]. Lymphangiectasia is one of the causes of dogs’ protein enteropathy [4]. Kleinschmid S. et al. (2006) detected intestinal lymphangiectasia among 38 of 64 dogs with chronic symptoms of alimentary tract diseases [7]. Lymphangiectasia is characterized by intestinal walls stratification preservation on ultrasound imaging [6] however Louvet A. and Denis B. (2004) described lymphangiectasia with intestinal thickening and loss of layering on ultrasound a 7-year-old West Highland White Terrier had with diarrhea, dysorexia, and weight loss. Initially, the authors suspected neoplastic or severe inflammatory disease [8].

Since the change in the echoicity of the intestinal mucosa is described both having pathology and among healthy animals after eating and quantitative changes of this indicator have not been determined we were interested in the quantitative characteristics of the echoicity of dogs and cats’ jejunum mucosa with different functional states of the bowel (fasted and in postprandial period).

2. Materials and methods
The objects of the study were healthy dogs and cats of both sexes of different ages and breeds. The studies were carried out at the Pirogov Veterinary Center, Stavropol in the period from May 2018 to December 2019. A total of 17 dogs aged 1 to 7 years and 14 cats aged 1 to 6 years were examined. The selection criterion was the absence of clinical signs of diseases of the digestive system in the anamnesis. Ultrasound was performed on a SIUI Apogee 1100 scanner (Shantou Institute of Ultrasonic Instruments Co., Ltd., Guangdong, China) according to the standard technique using a multi-frequency linear transducer with a frequency of 7-12 MHz. The study was carried out in two-dimensional gray-scale imaging modes (B-mode). The animals were examined before feeding with a preliminary 10-12 hour fasting diet, 20, 40, 60, 90, 120 and 180 minutes after feeding. For feeding we used ready-made dry food Purina® Dog chow® for adult dogs with a fat content of 12%, protein 25% and Purina® Cat Chow® for adult cats with a fat content of 11%, protein 32%. The duodenum was examined in the descending part behind the cranial bend. The jejunum was examined in the mesogastrium depending on the relative position of the transducer and the intestine, in the sagittal plane, in the transverse plane, and also in a number of lateral projections. Echohomogeneity and echoicity of the intestinal wall at each examination was determined by the method of Silina T L et al. (2010) [2]. To assess the echo uniformity of the intestinal layers we compared two zones of one layer located at the same distance from the transducer – the investigated and the background. For this purpose, the ultrasound image of the intestine was analyzed on a computer with licensed software Adobe Photoshop in black and white mode for which after turning on the histogram function the study area and the background area were highlighted tracing them 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 the graphical editor. For the background zone the "deviation error in the background zone" was additionally determined for which the background zone was divided into several sections determining the deviation value in each section of the background zone, the maximum deviation and the minimum deviation in the background zone or its sections were selected. Next, the deviation error in the background zone was calculated using the formula:

$$E_{Dev2} = Dev_{max} - Dev_{min}$$

where:

$E_{Dev2}$ – deviation error in the compared area;
Dev$_{\text{max}}$ – the maximum value of the deviation in the compared zone itself or its parts;
Dev$_{\text{min}}$ – the minimum value of the deviation in the compared zone itself or its parts.

Then the difference in deviations in the study area and in the background area was calculated using the formula:

$$\Delta \text{Dev} = \text{Dev}_1 - \text{Dev}_2,$$

where:
\(\Delta \text{Dev}\) – the difference in deviations in the investigated and compared areas;
\(\text{Dev}_1\) – deviations in the investigated area;
\(\text{Dev}_2\) – deviations in the compared area.

Comparison of the deviation error in the background zone with the difference in deviations in the investigated and background zones was made according to the formula:

$$\text{CEH} = E_{\text{Dev}2} - \Delta \text{Dev},$$

where:
CEH – echo-homogeneity criterion of the investigated area;
\(E_{\text{Dev}2}\) – deviation error in the compared area;
\(\Delta \text{Dev}\) – the difference in deviations in the investigated and compared areas.

Next, the difference between the arithmetic mean values of the brightness of the investigated and background areas was calculated according to the formula:

$$\Delta M_{\text{brt}} = M_{\text{brt}1} - M_{\text{brt}2},$$

where:
\(\Delta M_{\text{brt}}\) – the difference between mean values of the brightness;
\(M_{\text{brt}1}\) – mean values of the brightness in investigated areas;
\(M_{\text{brt}2}\) – mean values of the brightness in background areas.

Then, the modulus of the difference between the mean value of the brightness of the echo-homogeneity investigated area and the mean value of the brightness of the background area with the deviation in the background area was compared using the formula:

$$\text{CIS} = |\Delta M_{\text{brt}}| - \text{Dev}_2,$$

where:
CIS – investigated area isoechoic criterion;
\(|\Delta M_{\text{brt}}|\) – the modulus of the difference between the mean value of the brightness;
\(\text{Dev}_2\) – deviations in the compared area.

As a result of these calculations the degree of echo-homogeneity of the layers was determined.

Provided that one or another layer is homoechogenic, its echoicity was determined. The study area was defined as heteroechoic if \(\text{CEH} < 0\); isoechoic if \(0 \leq \text{CEH}, \text{CIS} \leq 0\); hyperechoic if \(0 \leq \text{CEH}, 0 < \text{CIS}, \Delta M_{\text{brt}} < 0\); hyperechoic if \(0 \leq \text{CEH}, 0 < \text{CIS}, 0 < \Delta M_{\text{brt}}\).

Numerical data were processed using one-way analysis of variance and Student’s test method for multiple comparisons the dependence was revealed in the course of correlation analysis by calculating the linear Pearson coefficient in the Primer of Biostatistics 4.03 software for Windows on an IBM PC-compatible computer.

3. Results

The ultrasound picture of dogs and cats’ jejunum is characterized by horizontally oriented linear structures in longitudinal scanning and rounded structures with radial orientation of the layers in transverse scanning with clear differentiation of layers of different echoicity. Ultrasound scanning allows to differentiate all layers of the intestinal wall: mucous, submucous, muscular, serous.

The intestinal cavity before feeding during longitudinal scanning is represented by a hyperechoic band the boundaries of which are determined by the contours of the mucous membrane (figure 1). A
small amount of gas may be present in the cavity while the cavity increases and the acoustic artifact of reverberation is superimposed on the intestinal wall farther from the ultrasonic sensor making it difficult to visualize this area.

**Figure 1.** Longitudinal scan of dogs’ small intestine before feeding. Left side: duodenum; the right side is the jejunum. The mucous membrane is represented by a thick hypoechoic line.

When determining dogs and cats’ duodenum and jejunum mucous membrane echoicity before feeding with a preliminary 10-12 hour fasting diet, we found that the quantitative indicators of echoicity in these departments are practically the same but these dogs’ indicators are significantly lower. Thus, the average value of the pixel brightness ($M_{brt}$) of dogs’ duodenal mucosa is $41.26 \pm 6.12$ and scatter degree of pixel brightness values is $10.32 \pm 3.14$. For the mucous membrane of the jejunum these figures are $40.37 \pm 5.67$ and $9.83 \pm 3.53$ respectively. The average value of pixels brightness of the mucous membrane of the duodenum of cats is $71.92 \pm 7.3$ and the scatter degree of the pixel brightness values is $11.56 \pm 3.42$. For jejunum mucous membrane these figures are $69.46 \pm 7.44$ and $12.01 \pm 2.73$ respectively. The mucous membrane of dogs and cats’ duodenum and jejunum before feeding is echo-homogeneous because the calculated homogeneity criterion (CEH) has a positive value, i.e. is above 0 and isoechoic criterion (CIS) does not exceed 0.

The ultrasound picture of dogs and cats’ small intestine changes after feeding. The size of the cavity increases due to the liquid inhomogeneous content, a pendulum movement of the contents is observed (figure 2). These presentations are most expressed 40, 60 and 90 minutes after feeding.

**Figure 2.** Dogs small intestine longitudinal scan after feeding. Left side: duodenum 18 months. Yorkshire Terrier 60 min. after feeding; the right side – the jejunum of a 3-year-old pug in 90 minutes after feeding. The intestinal cavity is enlarged with liquid inhomogeneous contents. In the mucosa multiple hyperechoic motlings are visualized.

64.7% of dogs have single and multiple hyperechoic inclusions not exceeding 0.15 cm and a longitudinal parallel hyperechoic mucosal line was recorded in the mucosa (figure 2). The CEH of the
mucous membrane of such animals had a value below 0, therefore its echoicity was characterized as heterogeneous. Intersperses in the mucous membrane were recorded from 40 minutes after feeding in the duodenum of 6 dogs, of 2 dogs in jejunum; 60 minutes after feeding – 10 dogs, both in the duodenum and jejunum; 90 minutes after feeding – in the duodenum of 8 dogs and in jejunum of 9 dogs. In subsequent observations the number of dogs with disseminations in the mucosa began to decrease and amounted to 6 and 8 by 120 minutes and 1 and 3 by 180 minutes in the duodenum and jejunum respectively (table 1). A longitudinal parallel hyperechoic mucosal line the thickness of which did not exceed 0.1 cm was recorded among 23.5% of dogs at time intervals from 60 to 120 minutes after feeding (figure 3, table 1). Among cats the heterogeneity of the mucous membrane was manifested only in the form of single hyperechoic inclusions presence. We registered a similar picture only among 21.4% of animals from 40 to 90 minutes after feeding.

![Figure 3](https://i.imgur.com/3.jpg)

**Figure 3.** Left side: duodenum of a 3-year-old Pekingese, longitudinal scan after 90 minutes after feeding; the right side is also labeled: parallel hyperechoic mucosal line (↓).

Among cats the heterogeneity of the mucous membrane was manifested only in the form of single hyperechoic inclusions presence. We registered a similar picture only among 21.4% of animals from 40 to 90 minutes after feeding.

| Table 1. Incidence of echographic changes in dogs and cats’ jejunum after feeding. |
|------------------------------|--------------|-----------------|-----------------|-----------------|
| Index                        | Research time: before and after feeding, min. | Animal species | Dogs (n=17) | Cats (n=14) |
|------------------------------|-----------------------------------------------|----------------|-------------|-------------|
| Mucosa single hyperechoic disseminations |                                | Intestinal segment | Duodenum | Jejunum | Duodenum | Jejunum |
| Before                       | 0                                             |                 | 0           | 0           | 0           | 0         |
| 20                           | 0                                             |                 | 0           | 0           | 0           | 0         |
| 40                           | 3                                             |                 | 1           | 2           | 0           | 0         |
| 60                           | 6                                             |                 | 5           | 3           | 3           | 3         |
| 90                           | 5                                             |                 | 5           | 2           | 3           | 3         |
| 120                          | 3                                             |                 | 4           | 0           | 1           | 1         |
| 180                          | 1                                             |                 | 2           | 0           | 0           | 0         |
| Before                       | 0                                             |                 | 0           | 0           | 0           | 0         |
| 20                           | 0                                             |                 | 0           | 0           | 0           | 0         |
| Mucosa multiple hyperechoic disseminations |                                |                   |             |             |             |           |
| Before                       | 0                                             |                 | 0           | 0           | 0           | 0         |
| 40                           | 3                                             |                 | 1           | 0           | 0           | 0         |
| 60                           | 4                                             |                 | 5           | 0           | 0           | 0         |
| 90                           | 4                                             |                 | 6           | 0           | 0           | 0         |
| 120                          | 3                                             |                 | 4           | 0           | 0           | 0         |
| 180                          | 0                                             |                 | 1           | 0           | 0           | 0         |
| Before                       | 0                                             |                 | 0           | 0           | 0           | 0         |
Since mucous membrane of most dogs was heterogeneous and it was impractical to determine its echoicity in areas with mottlings and stripes we evaluated the echoicity in homoechoic areas with a minimum spread in pixel brightness values. Quantitative indicators of echoicity of the mucous membrane of the duodenum and jejunum in both groups of animals after feeding fluctuated in different time intervals within 9% of the mean values obtained before feeding which was not statistically significant.

4. Discussion

As you know the basic principle of ultrasound is to compare the ultrasound image of one tissue (area) under study with the image of another, i.e. characteristic of the echoicity of a particular body structure. In the main scanning mode – B-mode (from the English "Bright" - "brightness") the ultrasound image is evaluated on the gray scale formed by the scanner based on the interaction of ultrasound with the tissues of the body. In this case, objects with different levels of brightness are visualized on the monitor. Since brightness is a subjective attribute of object’s properties perception, the analysis of changes detected during ultrasound examination based only on visualization can have different interpretations. A standard 8-bit image contains 256 different brightness levels the tool for its analysis is the brightness histogram which is a graph of the brightness gradient from zero (absolutely dim, black) to 255 (absolutely bright, white) and the number of image pixels that have the appropriate brightness. When analyzing the echoicity of the mucous membrane of dogs and cats’ jejunum we obtained a quantitative indicator $M_{\text{brt}}$ which is weighted average level of brightness of image pixels which is automatically calculated by 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.

The echoicity of the jejunum mucosa of cats does not change after feeding. We have not confirmed an increase in the echoicity of the mucous membrane of the jejunum after feeding dogs, as described earlier [4, 5]. So, Pollard R E et al. (2013) recorded an increase in mucosal echoicity of at least one segment of the jejunum (duodenum, jejunum, or ileum) after oral administration of corn oil among healthy dogs [4]. In this study, images were obtained using a 5-8 MHz transducer instead of a high-frequency transducer, which degrades the detail of structures and echoicity was assessed visually subjectively. In a study by Gaschen L. et al. (2016) presented data on an increase in the echoicity of the jejunum mucosa among dogs after eating where the authors gave a point characterization of echoicity (0, 1, 2) based on the presence of light mottlings in the mucosa [5]. In our opinion, this approach is methodologically incorrect since the presence of inclusions in the mucosa makes it heterogeneous and echoicity can be regarded as hyperechoic only in homoechoic structures [2].

In 35.3% of dogs and 78.6% of cats no changes in the mucous membrane of the duodenum and jejunum were found at various intervals after feeding. Changes in the mucous membrane of the duodenum and jejunum found in 64.7% of dogs in the form of small hyperechoic inclusions and a parallel longitudinal stripe which were absent before feeding, appeared 40 minutes after eating, persisted in most animals up to 120 minutes, and at 180 minutes were recorded only in 27 , 3%. These changes in the mucous membrane were manifested mainly in dogs of small breeds: Yorkshire Terrier, Pekingese, Pug, Toy Terrier and less often among dogs of medium and large breeds. The low incidence of changes in the mucous membrane among cats after feeding is probably related to the specific features of the digestive processes. The etiology of inclusions and stripes in the mucosa remains unclear but it has been suggested that they may be represented by dilated lymphatic vessels, local accumulations of mucus, cell debris, protein or gas in the crypts of the mucous membrane [9].
The origin of mottlings and stripes is apparently associated with the transport of fat through the lymphatic vessels of the villi and the lamina propria as evidenced by studies demonstrating the manifestation of symptoms on ultrasound of the intestine among dogs with histologically established lymphangiectasia after oral administration of corn oil [4]. The absence of clinical symptoms of diseases of the alimentary tract and the presence of changes in the mucous membrane during ultrasound before feeding as well as the disappearance of the described changes among most dogs by 180 minutes after feeding suggests that these changes are a variant of the norm.

5. Conclusion

Thus, the results of this study showed that the echoicity of the dogs and cats’ duodenal and jejunal mucosa does not change after feeding a balanced diet, however, among most dogs, single and multiple small inclusions and, less often, a longitudinal hyperechoic stripe appear in the mucosa. These changes are most expressed from 60 to 120 minutes after feeding and disappear by 180 minutes among most dogs. Only 21.4% of cats showed the presence of single hyperechoic inclusions in the mucous membrane of the duodenum or jejunum from 40 to 90 minutes after feeding. The described changes in the mucous membrane of the jejunum must be taken into account when ultrasound scan is performed on animal after a meal.

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