GASTROINTESTINAL ULTRASONOGRAPHY OF THE DOG

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CONTENTS

INTRODUCTION AND OBJECTIVES

During the last decades, ultrasonography has become an essential diagnostic imaging technique both in human and veterinary medicine. For a long time, the gas containing gastrointestinal (GI) tract was considered more of a hindrance of an abdominal sonographic examination than an organ system that can be assessed by ultrasonography. Nevertheless, with the aid of technical improvement and increased operator experience it became an accepted diagnostic technique of human GI examinations. Because, ultrasonography is an easy-to-use, non-invasive technique without ionizing radiation, it became particularly important in the diagnosis of different prenatal, neonatal and pediatric diseases, however it can replace other time consuming or invasive diagnostic techniques even in GI diseases of adults. Besides the possibility to study the GI wall, the lumen and the adjacent organs, real time visualization also allows the operator to observe the peristaltic activity of the GI tract. By the use of different Doppler techniques, more objective assessment of peristalsis became possible and the examiner is also able to gain information about the viability (by detecting blood flow) of a given segment of the GI tract.

The ultrasonographic appearance of the normal canine GI tract and some clinical applications of GI ultrasonography in dogs have been described (Penninck et al. 1989 and 1990, Penninck 1995). Changes in the thickness and appearance of the GI wall can be associated with pathological processes. Although these changes have been described during some GI diseases of the dog, no experimental in vitro validation was done to correlate the in vivo and in vitro ultrasonographic appearance of the different morphological alterations of the GI tract. The comparison of the GI lesions observed in vivo by the ultrasound with the in vitro sonographic appearance of these parts following surgical or pathological dissection can be beneficial to improve the diagnostic accuracy of both the technique and the examiner. However, these in vitro ultrasound examinations may hamper further histopathological examinations if performed prior to fixing with formaldehyde solution. Description of the effect of formaldehyde fixation on the in vitro appearance and wall thickness of the intestines is lacking in both veterinary and human medicine to our knowledge.

The aim of my first study was to compare the in vivo and in vitro ultrasonographic appearances and wall thickness measurements of the GI tract of the dog and those of

isolated GI segments before and after formaldehyde fixation. This experiment was intended to decide whether formaldehyde cause any artificial change in the ultrasonographic image of the intestines.

Ultrasonography of the abdomen in general and that of the GI tract in particular, may be hampered by gas within the GI tract. In humans, patient preparation, by way of withholding food and administration of laxatives, had an unpredictable effect on the quality of ultrasonographic examinations (Meire and Farrant 1978). The consumption of degassed fluids before the examination in humans improved the sonographic picture of the stomach and duodenum (Joharjy 1990, Mittelstaedt 1992). Fluid administration via a stomach tube has been recommended in the dog to enhance visualization of suspected intramural or luminal lesions of upper segments of the gastrointestinal tract (Kleine and Lamb 1989, Penninck et al 1989). For decades, radiography of the canine abdomen has been used to examine the gastrointestinal tract and it is common use to administer barium into the gastrointestinal tract when survey radiographs are not diagnostic. These contrast studies include selective filling of the stomach, the small intestines following intubation of the duodenum, and the colon. Furthermore, the small intestines may be studied using the small bowel follow through (SBFT) study, following contrast administration into the stomach, or the reflux examination, following contrast administration into the colon. Double contrast studies have been performed of the stomach and colon using barium and air, and of the small intestines using barium and water, following intubation of the duodenum (Kealy 1987, Kleine and Lamb 1989, Wolvekamp 1989, Burk and Ackerman 1996, Konde and Pugh 1996).

A systematic ultrasonographic examination of the canine GI tract using selective filling of stomach, small intestines, or colon, with fluid, comparable to the selective filling of these parts of the GI tract for contrast radiography, can not be found in the veterinary literature.

The purpose of my second study was to assess the effect of fluid administration to the stomach for a SBFT study, the enteroclysis technique, and the reflux examination on the quality of ultrasonographic images of the gastrointestinal tract in healthy dogs. During these experiments I intended to decide, which of these techniques is most suitable for improving the ultrasonographic image of the canine GI tract.

Partial or complete obstruction of the small intestine of the dog can be caused by indigestible foreign material, masses of parasites, postoperative adhesions, neoplasm, granulomas, abscesses, volvulus, intussusception and hernial incarceration. Paralysis of a segment or that of the entire small bowel caused by peritonitis, enteritis, pancreatitis, certain drugs, or following laparotomy may cause signs of intestinal obstruction (Fraser, 1991). Reports on the sonographic appearance of canine intestinal ileus are limited to that of the gastrointestinal foreign bodies, invagination and paralytic ileus (Fluckiger and Arnold, 1986; Kantrowitz et al., 1988; Penninck et al., 1990; Watson et al., 1991; Tidwell and Penninck, 1992; Kramer and Gerwing, 1996). Numerous authors have described the sonographic findings of small intestinal obstruction in human beings. There are also sonographic criteria for the diagnosis of this disorder in humans (Ko et al., 1993; Ogata et al., 1994 and 1996; Truong et al. 1992).

The aims of my third study was to establish similar sonographic criteria and evaluate their efficacy in the diagnosis of intestinal obstruction of the dog.

I also intended to investigate how ultrasonography can be integrated into the diagnostic process of canine intestinal obstruction. Human clinical studies found ultrasonography to be a useful diagnostic technique in the differential diagnosis of different forms of ileus (Meiser and Meissner 1987, Truong et al. 1992, Ogata et al. 1994). A prospective study regarded ultrasonography to be as sensitive and more specific than plain film radiography in the diagnosis of bowel obstruction of humans (Ogata et al. 1996). Others reported the sensitivity of ultrasonography higher than conventional radiography in diagnosing small bowel obstruction and strangulation (Ko et al. 1993, Czechowski 1996). Similar comparative studies have not been reported in veterinary medicine.

The objective of my fourth study was to compare the diagnostic value of ultrasonography with that of plain film radiography in canine intestinal obstruction.

Changes in the thickness and/or structure of the GI wall, in the diameter and content of the lumen, and in the peristalsis are consistent ultrasonographic features of gastrointestinal disorders. The observed ultrasonographic changes have been reported in certain gastrointestinal disorders of the dog (Penninck 1995). These observed ultrasonographic alterations, however have not been assessed on a large number of clinical cases.

The objectives of my fifth study were to observe the ultrasonographic changes on a large number of clinical cases, and to try to determine the diagnostic value of these sonographic alterations. My final goal was to combine my findings with those of other authors in order to determine the role of ultrasonography in the diagnosis of canine gastroenterological diseases.

CHAPTER I

COMPARISON OF IN VIVO AND IN VITRO ULTRASONOGRAPHIC APPEARANCES AND WALL THICKNESS MEASUREMENTS OF THE CANINE INTESTINAL TRACT

There is increasing use of ultrasonography during the diagnosis of various GI disorders both in human and veterinary medicine (Mittelstaedt 1992, Penninck 1995). The normal ultrasonographic appearance and wall thickness of the intestinal tract of the dog and humans have been described (Kimmey et al. 1989, Penninck et al. 1989, Silverstein et al. 1989, Wiersema and Wiersema 1993). According to these reports, the GI wall has a typical layered appearance with five layers visible when transducers of higher frequencies are used. These layers from lumen to serosa are the followings:

- an inner hyperechoic layer representing the interface between the lumen and the mucosa,
- a hypoechoic layer representing the remainder of mucosa,
- a middle hyperechoic layer representing the submucosa and interfaces between submucosa, mucosa and the muscular layers,
- a hypoechoic layer corresponding to the rest of the muscular layer,
- an outer hyperechoic layer representing the interface between the muscular layer and serosa (*Fig.1*).

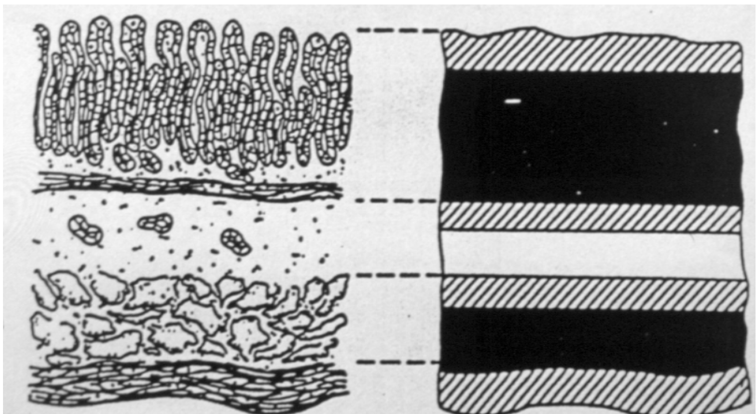


Fig. 1. Relationship between the ultrasound image and the layers of the normal bowel wall. Diagonally hatched areas represent interface echoes, which will appear hyperechoic. (Wiersema and Wiersema 1993).

The normal wall thickness of the stomach and duodenum of the dog ranges from 3-5 mm, while that of the small and large intestines ranges from 2-3 mm (Penninck 1989, Lamb and Simpson 1995). Besides the ultrasonographic appearance of the normal canine GI tract, some clinical applications of GI ultrasonography in dogs have been also described (Penninck et al. 1990, Penninck 1995). Changes in the thickness and appearance of the GI wall can be associated with pathological processes. Although these changes have been described during some GI diseases of the dog, no experimental in vitro validation was done to correlate the in vivo and in vitro ultrasonographic appearance of the different morphological alterations of the GI tract. The comparison of the GI lesions observed in vivo by the ultrasound with the in vitro sonographic appearance of these parts following surgical or pathological dissection can be beneficial to improve the diagnostic accuracy of both the technique and the examiner. However, these in vitro ultrasound examinations may hamper further histopathological examinations if performed prior to fixing with formaldehyde solution. Description of the effect of formaldehyde fixation on the in vitro appearance and wall thickness of the intestines is lacking in both veterinary and human medicine to our knowledge. The aim of this study was to compare the in vivo and in vitro ultrasonographic appearances and wall thickness measurements of the GI tract of the dog and those of isolated GI segments before and after formaldehyde fixation.

MATERIALS AND METHODS

Eight dogs that were due to be euthanised because of untreatable disorders not related to the gastrointestinal tract were selected for this study. All dogs underwent routine abdominal ultrasonography before euthanasia using a 7 MHz mechanical sector and/ or a 5 MHz convex array transducer (Brüel & Kjaer 1846, Brüel & Kjaer, Panther 2002, Naerum, Denmark). The dogs were fasted for 24 hours before the examinations. The abdominal skin was prepared as for a routine abdominal ultrasound examination (clipping of the hair, wetting with ultrasound gel.) The appearance of their gastrointestinal tract were observed and the wall thickness of the descending duodenum and some jejunal loops were measured between the hyperechoic mucosal and serosal surface by internal machine calipers. Later, 10-15 cm long segments of the descending duodenum, the jejunum and the descending colon were cut out following euthanasia (within 4 hours). The isolated intestinal segments were cleaned with flushing using tap water in two dogs and physiologic saline solution in the other six animals. The intestinal parts were cut in half in seven dogs. One half of the segments were used for an immediate ultrasound examination in waterbath, using the same bathing fluid in each case that was also used during the earlier cleaning process. The intestinal segments were immersed in the bathing fluid and the transducer was placed on the fluid surface, about 4-6 cm distance from them. The other parts of the intestinal segments were fixed in 10% neutral formaldehyde solution for at least a week before the ultrasound examination. Tap water was used as waterbath medium during the ultrasound examination of the formaldehyde fixed intestines. Wall thickness measurements at three different points were made in saggital and transverse section of both the formaldehyde fixed and unfixed duodenum, jejunum and colon segments. Full thickness samples were obtained for histological examination from the formaldehyde fixed intestines.

RESULTS

The in vivo ultrasonographic appearance of the gastrointestinal tract had the same features as described in the literature (Kimmey et al. 1989, Penninck et al. 1989, Silverstein et al. 1989, Wiersema and Wiersema 1993). With the use of the 7 MHz transducer all five layers of the small intestinal wall were visible (*Fig.2*).

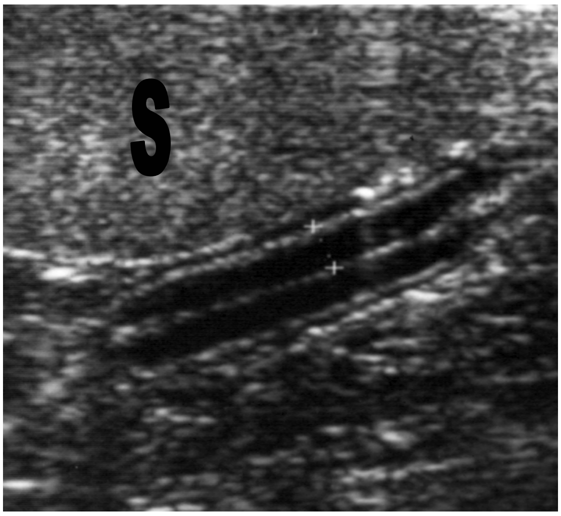
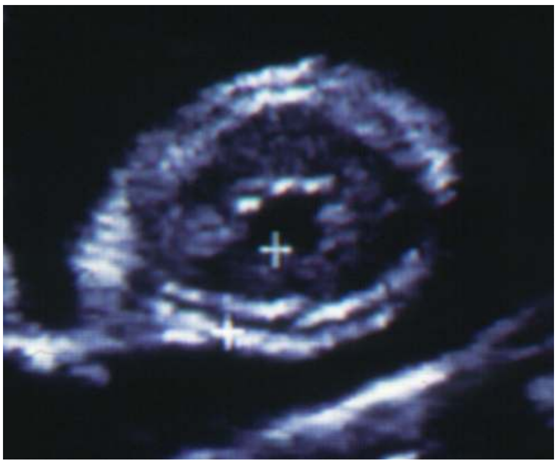


Fig. 2. Ultrasound image of a small intestinal segment in saggital section. The five layers of the bowel wall is clearly visible. The mucosal surface, mucosa and submucosa are marked between machine calipers. The spleen (S) is visible on the top of the picture.

In vivo assessment and measurement of the wall of the colon was not possible in any of the dogs, because of the disturbing effect of intraluminal gas and fecal content. Placing the intestinal specimens into waterbath enabled a more detailed observation of the gastrointestinal wall layers (*Figs 3. and 4.*). The formaldehyde fixation did not change the ultrasonographic appearance of the intestinal segments (*Fig 5.*). The results of in vivo and in vitro wall thickness measurements are shown in *Table 1*. All intestinal segments were considered normal based on the result of the histological examination.



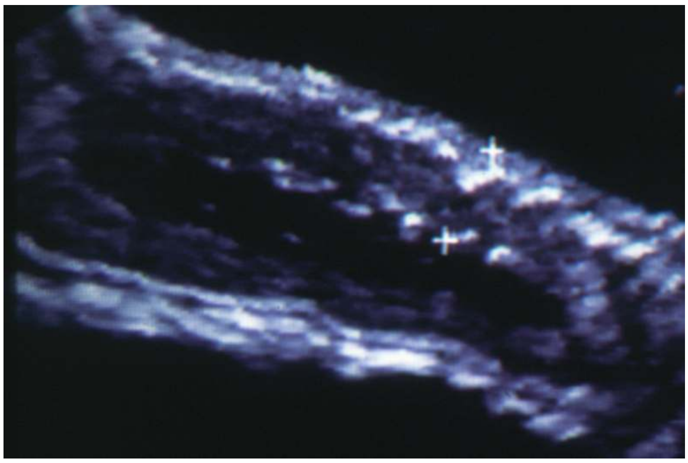


Fig. 3. and 4. Cross sectional and saggital ultrasound images of an isolated duodenum segment in waterbath. The five layers of the bowel wall is clearly distinguishable. Machine calipers are placed to the luminal and serosal surface of the bowel wall.

Fig. 5. Cross sectional ultrasound image of an isolated duodenum segment in waterbath after one-week long formaldehyde fixation. The appearance of the intestinal wall layers is the same as that of the fresh, unfixed specimens. Machine calipers are placed on the serosal and mucosal surface of the bowel wall.

Dog No.	Data of the dogs (breed, age, sex)	In vivo wall thickness measurements (in mm)	In vitro wall thickness measurements (in mm)	In vitro wall thickness measurements after formaldehyde fixation (in mm)
1.	Great Dane, 1 year, female	duodenum: 4 jejunum: 3 colon: -	Duodenum: 6-7 Jejunum: 5-5 Colon: 5-4	duodenum: 5-6 jejunum: 4-3 colon: 3-4
2.	Mixed breed, 10 years, male	duodenum: 5 jejunum: 3 colon: -	Duodenum: 4.5-4 Jejunum: 4-4 colon: -	duodenum: 4-4 jejunum: 3-3 colon: -
3.	Bernese mountain dog, 11 years, female	duodenum: 4.5 jejunum: 2.8 colon: -	Duodenum: 7-5.8 Jejunum: 5-5.8 Colon: 3.7-3.7	duodenum: 4.5-5 jejunum: 5-4.5 colon: 5.8-4
4.	English setter, 5 year old, male	duodenum: 4 jejunum: 4 colon: -	Duodenum: 4-4 Jejunum: 3-3 colon: -	duodenum: 5-5 jejunum: 3-3 colon: -
5.	Dogo argentino, 8 months, male	duodenum: 4.5 jejunum: 2.8 colon: -	Duodenum: 4.5-4.1 Jejunum: 3.7-3.7 Colon: 3.7-4.1	duodenum: 5.4-5 jejunum: 4.3-3.8 colon: 3-3.7
6.	Dogo argentino, 8 months, male	duodenum: 4.2 jejunum: 2.5 colon: -	Duodenum: 5-5 Jejunum: 3.6-3.7 Colon: 4-4.1	duodenum: 4.1-4.5 jejunum: 3.7-4.1 colon: 5-4.5
7.	Bernese mountain dog, 5 years, female	duodenum: 3.7 jejunum: 2.5 colon: -	Duodenum: 4-4 Jejunum: 2.5-2.5 Colon: 4.1-4.1	duodenum: 5.8-5.4 jejunum: 3.6-4.1 colon: 4.5-5.4
8.	Mixed breed, 5 years, male	duodenum: 4 jejunum: 2.8 colon: -	Duodenum: 3.7-3.1 Jejunum: 2.4-2.6 colon: -	-

Table 1. The results of the in vivo and the in vitro ultrasonographic measurements of the intestines prior and following formaldehyde fixation. The numbers separated with a hyphen indicate the averages of three-three wall thickness measurements in saggital and transverse sections, respectively.

DISCUSSION

The formaldehyde fixation did not change the ultrasonographic appearance of the intestinal segments, thus in vitro ultrasonographic examination of different pathological processes of the intestines is possible following formaldehyde fixation.

The result of in vivo wall thickness measurements were accordance with earlier reports in all but one dog (dog No. 4). The in vitro wall thickness measurements resulted in higher values than the in vivo measurements did in five of the eight dogs.

There are different factors that may have contributed to this latter finding. Firstly, smooth muscle contraction after death may have played a role in the thickening of the intestines. Secondly, the waterbath fluid may have had an effect on the intestinal segments in two dogs (dog No.1 and No.2), where tap-water was used both during the cleaning of the intestinal lumen and also as waterbath medium. This may have caused thickening of the intestines due to the osmotic effect of tap water. However, isotonic saline solution was used in all other cases, thus in those cases osmotic differences should not have played a role in the higher values of in vitro measurements. Thirdly, the different measured thickness of the same intestinal segment in different planes raise the suspicion of possible measurement errors. This may also explain the higher than normal wall thickness of the jejunum that was measured in vivo in dog No.4. The transducer position is of special importance during ultrasonographic measurements. Erroneously higher data of the intestinal wall thickness will be measured in saggital view when the transducer is not hold precisely perpendicular to the longitudinal axis of the intestinal segment or when the scanning is performed in parasaggital section. The higher is the distance of the scanning plane from the midsaggital section of the intestine and the higher is the degree of the incident beam from the perpendicular direction, the greater is the alteration from the real value in saggital section. The situation is slightly different when the intestines are viewed in transverse plane. Unintentional tilting or turning the transducer from transverse plane will produce falsely thicker measurements of the intestinal wall only if certain parts of the intestinal wall are used for the measurements. Tilting the transducer from transverse plane will cause erroneous measurement if the part closest to and most far away from the transducer are used for measuring. On the contrary, rotation will affect the measurements only if not these parts of the intestinal segments are used for the measurements. The higher is the alteration from transverse plane in any direction, the higher the measurement error will be.

The following conclusions can be drawn from this study:

1. **The formaldehyde fixation did not change the appearance of the intestinal segments, thus in vitro ultrasonographic examination of different pathological processes of the intestines is possible following formaldehyde fixation.**

2. **In vitro ultrasonographic measurements are affected by various factors, that should be considered when comparing them with in vivo ultrasonographic measurements.**

3. **To minimize erroneous ultrasonographic measurement of the gastrointestinal tract, the transducer should be always kept perpendicular to a gastrointestinal segment and measurement should be done when the largest luminal diameter, hence the thinnest wall thickness is observed in saggital section. On the contrary, measurements in transverse view should be done when the smallest and most circular luminal area is observed.**

CHAPTER II

FLUID AIDED ULTRASONOGRAPHY OF THE GASTROINTESTINAL TRACT IN HEALTHY BEAGLES

The ultrasonographic appearance of the normal canine gastrointestinal tract and some clinical applications of gastrointestinal ultrasonography in dogs have been described (Penninck et al. 1989 and 1990, Penninck 1995). Ultrasonography of the abdomen in general and that of the gastrointestinal tract in particular, may be hampered by gas in the gastrointestinal tract. In humans, patient preparation, by way of withholding food and administration of laxatives, had an unpredictable effect on the quality of ultrasonographic examinations (Meire and Farrant 1978). The consumption of degassed fluids before the examination in humans improved the sonographic picture of the stomach and duodenum (Joharjy 1990, Mittelstaedt 1992). Fluid administration via a stomach tube has been recommended in the dog to enhance visualization of suspected intramural or luminal lesions of upper segments of the gastrointestinal tract (Kleine and Lamb 1989, Penninck et al 1989).

For decades, radiography of the canine abdomen has been used to examine the gastrointestinal tract and it is common use to administer barium to the gastrointestinal tract when survey radiographs are not diagnostic. These contrast studies include selective filling of the stomach, the small intestines following intubation of the duodenum, and the colon. Furthermore, the small intestines may be studied using the small bowel follow through (SBFT) study, following contrast administration to the stomach, or the reflux examination, following contrast administration to the colon. Double contrast studies have been performed of the stomach and colon using barium and air, and of the small intestines using barium and water, following intubation of the duodenum (Kealy 1987, Kleine and Lamb 1989, Wolvekamp 1989, Burk and Ackerman 1996, Konde and Pugh 1996).

A systematic ultrasonographic examination of the canine gastrointestinal tract using selective filling of stomach, small intestines, or colon, with fluid, comparable to the selective filling of these parts of the gastrointestinal tract for contrast radiography, can not found in the literature.

The purpose of the present study was to assess the effect of fluid administration to the stomach for a SBFT study, the enteroclysis technique, and the reflux examination on the quality of ultrasonographic images of the gastrointestinal tract in healthy dogs.

MATERIALS AND METHODS

Ultrasonographic examinations of the GI tract were performed on 9 clinically healthy beagles. There were 5 males and 4 females. The dogs were between 3.5 and 11 years of age (mean 9 years) and weighed between 10 and 18.5 kg (mean 14.5 kg).

All ultrasonographic examinations were performed using a high definition ultrasound system equipped with a 5-3 and a 7-4 MHz broadband phased array, and a 10-5 MHz broadband linear array transducer.* The actual choice for a transducer depended on both the size of the dog and on the depth of the area of interest. Images were recorded on videotape for subsequent evaluation.

The dogs were fasted for 24 hours before the examinations. The abdominal skin was prepared as for a routine abdominal ultrasound examination (clipping of the hair, wetting with ultrasound gel.) All ultrasonographic examinations (before and following fluid administration) were performed on the dogs in dorsal and right lateral recumbency. When the pylorus and the proximal part of the duodenum could not be identified using this approach, the dogs were positioned oblique between dorsal and right lateral recumbency. When gas containing parts of the gastrointestinal tract interfered with the transmission of ultrasound, scanning from the dependent side of abdomen was tried. Often a slight increase of pressure with the transducer was used to displace superficial, gas containing intestinal loops.

Before any fluid was administered to the GI tract, an initial ultrasonographic examination of the abdomen was performed in every dog. Seven dogs were examined following administration of fluid to the stomach through a gastric tube. In 3 of these 7 dogs a reflux examination was performed following the administration of fluid to the colon, and another 3 of these 7 and 2 other dogs were examined following selective filling of the small intestines with fluid following intubation of the duodenum. When dogs were examined twice, there were at least 2 weeks in between examinations.

Fluid administration to the stomach and SBFT study

Small bowel follow through studies were performed in conscious dogs with only minimal manual restraint. Fluid was administered through a gastric tube: 10 ml/bwkg 2.2 % carboxymethylcellulose (CMC)† solution in 5 dogs, 10ml/bwkg tap water in 1 dog and 10 ml/bwkg soluble iodide radiographic contrast medium‡ in another one. All 7 dogs were examined ultrasonographically at 5-10 and 10-20 minutes after the fluid administration. Four dogs (among whom 2 received CMC solution, 1-1 received tap water and radiographic contrast respectively) were further scanned 3-4 times similarly to a radiographic SBFT study at 20-40, 40-60, 60-90, 90-150 and 150-210 minutes following fluid administration. Ventrodorsal and left lateral radiographs were also made in the dog that received radiographic contrast medium at 0,15,30,45,60 and 120 minutes after the contrast material was given.

Enteroclysis examination

Following sedation with 0.3-0.5 mg/bwkg acepromazine maleate§, a tube with a guidewire was inserted through a mouth-gag into the stomach and then into the duodenum under fluoroscopic control. This procedure is described in detail elsewhere (Wolvekamp 1989). The tube was attached to an enema bag and the small intestines were filled completely with 800-1000 ml warm CMC solution in 4 dogs, and 800 ml warm radiographic contrast material in 1 other dog, by the force of gravity. This was constantly monitored by ultrasonography. The infusion was terminated when the fluid column reached the colon. The infusion rate varied from 57 to 133 ml/min. In 2 dogs, 200 and 140 ml additional fluid was injected into the rectum from a large syringe in order to enhance visualization of the large intestine. Ventrodorsal and laterolateral radiographs were also taken from the dog that received radiographic contrast medium at the time when all intestinal loops were distended.

Reflux examination

All three dogs were sedated with medetomidine hydrochloride¶ (40-60 (μg/kg iv.) One dog was also given propofol** additionally (1 mg/kg iv.) Following multiple high-volume warm water cleansing enemas, a balloon-catheter attached to an enema bag was inserted into the rectum. The balloon was insufflated and the colon and the small intestines were filled with 1000-1300 ml warm, isotonic saline solution from the enema bag by the force of gravity in all 3 dogs. This was constantly monitored by ultrasonography. The flow of the fluid was stopped when the fluid column reached the descending duodenum. The infusion rate varied from 100 to 140 ml/min. After the examination, the enema bag was lowered in order to remove the fluid from the GI tract. The dogs were awakened with an atipamezole hydrochloride†† ((2.5 times the dose of the originally used medetomidine) injection.

All ultrasonographic examinations were focused on the gastrointestinal tract. Gastrointestinal wall recognition, the nature of luminal content (fluid-, mucus-, or gas pattern) and the presence of peristalsis were the main criteria for the assessment of the quality of the sonographic images. The stomach and the proximal duodenum, the small intestines and the large intestines were separately assessed and graded in each dog according to the following grading system:

Grade 1. : Very poor visualization of the GI wall, mainly gas pattern.

Grade 2. : Poor visualization of the GI wall, more parts with gas artifacts than with mucus or fluid pattern.

Grade 3. : Moderate visualization of the GI wall, approximately the same amount of mucus or fluid pattern as gas pattern.

Grade 4. : Good visualization of the GI wall, mainly mucus or fluid pattern with few gas artifacts.

Grade 5.: Excellent visualization of the GI wall, mainly fluid pattern with some areas with mucus pattern, without any gas artifacts.

*HDI 3000, Advanced Technology Laboratories, Woerden, The Netherlands

† CMC sodium 2.2 %, prepared from carboxymethylcellulose sodium, Metsä-Serla Chemicals B.V., Nijmegen, The Netherlands

‡ Hexabrix 320, Guerbet Nederland B.V., Gorinchem, The Netherlands

§ Vetranquil, Sanofi Sante B.V., Maasluis, The Netherlands

¶ Domitor, SmithKline Beecham Animal Health BV, Zoetermeer, the Netherlands

** Diprivan, Zeneca BV, Ridderkerk, the Netherlands

†† Antisedan, SmithKline Beecham Animal Health BV, Zoetermeer, the Netherlands

RESULTS

Initial examination

The quality of the images of abdominal ultrasonography before fluid application varied from dog to dog. The stomach always contained some gas that made the assessment of the whole organ difficult or even impossible. The small intestines showed gas and mucus pattern in varying distribution. Peristalsis could be well observed as swirling movement of the echogenic ingesta particles or movement of the gas content together with the contraction of the GI segment. Evaluation of the colon was always impossible due to intraluminal gas and/or fecal material.

Fluid administration to the stomach and the SBFT study

The fluid administration through a gastric tube was always easily achieved with minimal manual restraint in all the 7 dogs. The results of the initial scan and those of the scans following fluid administration together with the time intervals in minutes after fluid administration are summarized in *Table 2.1*.

Dog No.	**Fluid**	**Results of the initial scans**	**5-10 min.**	**10-20 min.**	**20-40 min.**	**40-60 min.**	**60-90 min.**	**90-150 min.**	**150-210 min.**
1.	CMC	2-3 3 1	3 3 1	3-4 3 1	2-3 3-4 1	2-3 3-4 1	2 3 1	-	2-3 3 1
2.	CMC	2 2 1	1-2 2 1	4-5 2-3 1	4-5 3 1	3 3 1	-	1-2 2-3 1	2 2-3 1
3.	iodide contrast	2 3 1	1-2 3 1	1-2 3 1	1-2 3 1	1-2 3-4 1	2 2-3 1	3-4 3-4 1-2	-
4.	water	2-3 2-3 1	3 3 1	3-4 3 1	1-2 3-4 1	-	-	2-3 2 1	3 2-3 1
5.	CMC	3-4 3 1	4 3 1	2-3 3 1					
6.	CMC	2 2-3 1	3-4 2-3 1	4 3 1					
7.	CMC	2-3 3 1	1-2 3 1	3 3 1					

Table 2.1 The results of fluid administration to the stomach. In the upper row the numbers in minutes indicate the time after fluid administration. The number(s) in the cells indicate the grades given for the ultrasonographic quality of the stomach and proximal duodenum (top), the rest of the small intestines (middle) and the large intestines (bottom), respectively. CMC: carboxymethylcellulose

A moderate distension of the stomach was immediately noted, but the image quality improved after 5-10 minutes following fluid administration. The only exception was dog No.3 in which a large amount of air was present in the stomach before the fluid application. In that case the stomach could not be examined at all until it had emptied with only a minimal gas remaining in its lumen *(Fig 2.1)*. In 5 of the dogs (not in dog No.2 and No.4) small echogenic bubbles were noted following the fluid administration. Even though it was slightly disturbing, it did not make the visualization of the stomach wall impossible *(Fig 2.2)*.

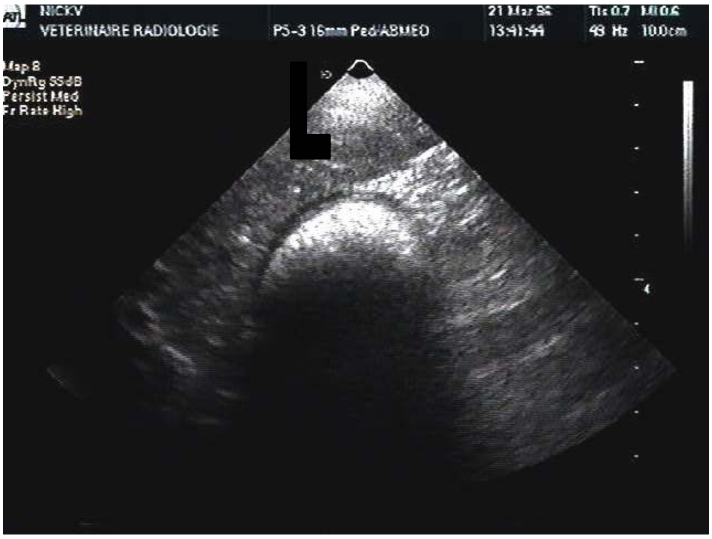


Fig. 2.1 Ultrasonographic image of the stomach with large amount of intraluminal gas in transverse view (dog No.3). Only the wall closer to the transducer can be visualized, other parts of the gastric wall are covered by gas artifact (shadowing). The liver (L) is visible on the left of the image.

Fig. 2.2 Ultrasonographic image of the stomach in transverse view. Small echogenic bubbles are present in the lumen after fluid administration through a gastric tube (dog No.5). Both close and far wall of the stomach can be clearly visualized. The layered appearance of the gastric wall is easily recognizable. The liver is visible on the top of the image.

The stomach emptying started immediately following the fluid application and after 45-90 minutes the stomach was empty. The passing fluid helped to identify and better visualize the pylorus and duodenum *(Fig.2.3).*

Fig. 2.3 Ultrasonographic image of the pylorus and the proximal part of the duodenum during gastric emptying of fluid in dog No.3. Intraluminal fluid created better circumstances to visualize the pylorus, however gas bubbles are causing artefact that partly covers the wall of the pyloric canal on the picture (white arrow).

The peristaltic contractions and the movement of the luminal content was readily visible throughout the gastrointestinal tract. Peristaltic activity was increased by fluid administration. In case of the beagle (dog No.3) that received iodide contrast material, contrast in the stomach (0 min.), contrast in the stomach and in the cranial small intestinal loops (15-30 min.), contrast in the stomach and in the caudal small intestinal loops (45, 60 min) and eventually contrast in the caudal small intestines and in the colon (120 min.) could be seen on the series of radiographs *(Fig.2.4-6).* During the almost simultaneously performed sonographic examinations, the stomach emptying (from 5 to 60 minutes after fluid application) and some dilated small intestinal loops with peristaltic activity (from 5 to 120 min. after fluid administration), and eventually some fluid in the colon (120 min. after fluid application) were recognized. The identification of the different small intestinal segments - except the duodenum - was not possible. The findings in the remaining dogs were similar to this beagle: as the fluid passed through the small intestinal loops it increased the quality of their sonographic image (causing slight distension and rather mucus than fluid pattern) but it was not possible to identify the different intestinal segments *(Fig.2.7).* Some parts of the intestines always contained gas and therefore were missed during the examination. The evaluation of the entire colon was not possible in any of the dogs (even if some fluid reached it from cranial direction), because of the disturbing effect of gas and/or fecal material present in its lumen.

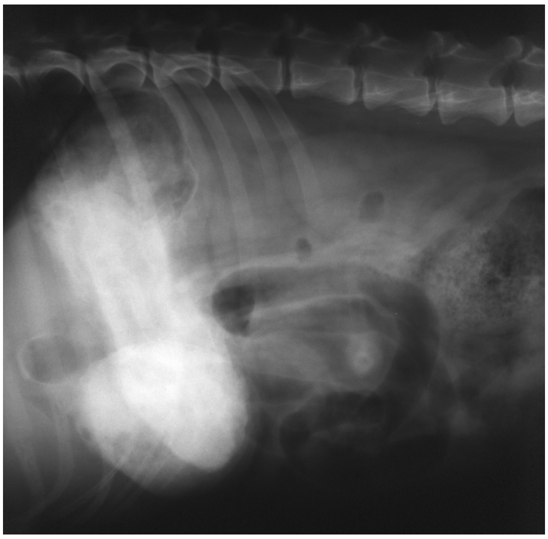


Fig. 2.4 Lateral radiograph of the abdomen of dog No.3 taken immediately following iodide contrast administration to the stomach. The contrast material is visible in the stomach.

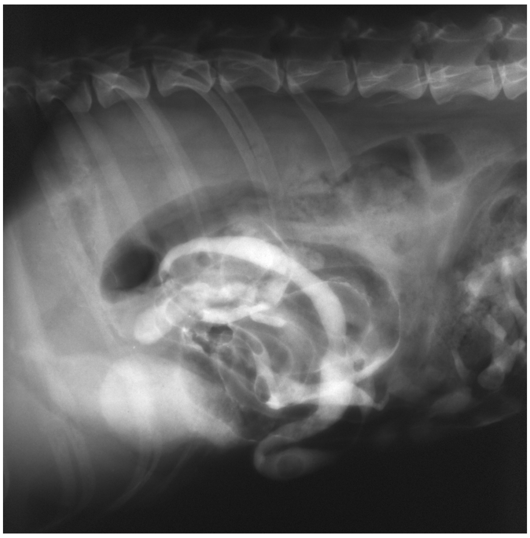


Fig. 2.5 Lateral radiograph of the abdomen of dog No.3 taken 45 minutes following iodide contrast administration to the stomach. The contrast material is visible in the stomach and in some jejunal loops.

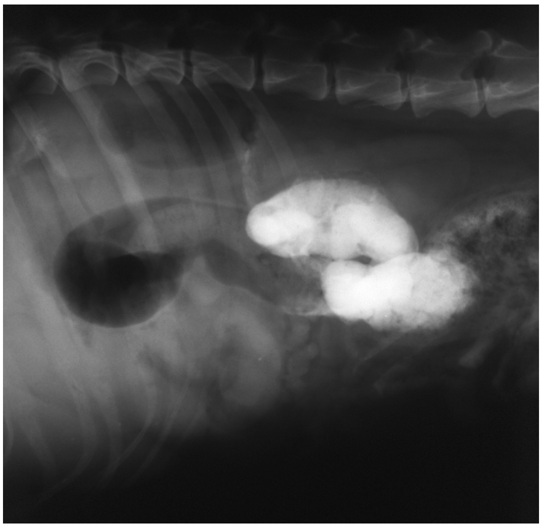


Fig. 2.6 Lateral radiograph of the abdomen of dog No.3 taken 120 minutes following iodide contrast administration to the stomach. The contrast material is visible in the colon.

Fig. 2.7 Ultrasonographic image of two small intestinal loops in sagittal section during the SBFT study in dog No.6. The lumens (white arrows) are hyperechoic due to small gas bubbles in the intraluminal fluid. The bowel wall structure is not recognizable and seems hypoechoic.

Enteroclysis

The acepromazine sedation was not satisfactory and considerable manual restraint was needed during the insertion of the tube to the stomach and then through the pylorus into the duodenum, however once the tube was in place the sedation proved satisfactory during the ultrasonographic examination. The time needed for duodenal intubation varied from 2 minutes to almost 30 minutes. The infusion of fluid caused distension of the duodenum and subsequently of all the aboral intestinal loops. There was always some reflux to the stomach. At the time when all of the small intestinal loops were distended, showing fluid pattern, and were transiently paralyzed, the infusion was stopped *(Fig 2.8)*. During filling, the infusion rate was adjusted to the desirable effect by changing the height of the enema bag. As the tube was removed from the duodenum larger amount of reflux occurred to the stomach, but it never caused vomiting in any of the dogs. This reflux caused a fluid pattern in the distended stomach *(Fig2.9)*.

After 3-5 minutes paralytic state the peristalsis returned and the fluid gradually disappeared from the small intestine. As the fluid reached the colon from cranial direction, this helped to better visualize the colon wall but visualization of the whole large intestine was not possible - even when some fluid was injected into the rectum, because of the disturbing effect of gas or fecal material present in its lumen. On the radiographs, that were obtained from the dog No.1 at the time of complete filling, a contrast filled stomach together with the completely contrast filled small and large intestines were seen *(Fig 2.10)*. The results of the initial scan and those of the scans following fluid administration are summarized in *Table 2.2*. The time needed for the complete filling of the intestines and the effect of additional fluid administration to the rectum are also included in the table.

Dog No.	Fluid type	Results of the initial examination	Image quality at the time of complete filling	Time for complete filling	Additional per rectal fluid and the image quality of the rectum
1.	800 ml iodide contrast solution	3 3 1	4 4 3-4	6 min.	130 ml tap water rectum: 4
2.	1000 ml CMC	2 2-3 1	4 4-5 1	10 min.	-
4.	800 ml CMC	3-4 3 1	4-5 4 1	14 min.	200ml CMC rectum: 2-3
8.	900 ml CMC	3 3 1	4 4 1	8 min.	-
9.	1000 ml CMC	1-2 2-3 1	2 4-5 1	18 min.	-

Table 2.2 Results of the enteroclysis examination. The number(s) in the cells indicate the grades given for the ultrasonographic quality of the stomach and proximal duodenum (top), the rest of the small intestines (middle) and the large intestines(bottom), respectively. CMC: carboxymethylcellulose

Fig.2.8 Enteroclysis examination. Ultrasonographic image of fluid filled small intestinal loops in. transverse view dog (No.9). The intestinal lumen contains anechoic fluid. Note the prominent innermost hyperechoic layer of the bowel wall. The spleen is visible in the top of the picture.

Fig. 2.9 Enteroclysis examination. Ultrasonographic image of the fluid filled stomach in transverse view (dog No.2). Reflux to the stomach caused distension of the organ and the anechoic fluid in the lumen created optimal circumstances for the visualization of the layers of the gastric wall.

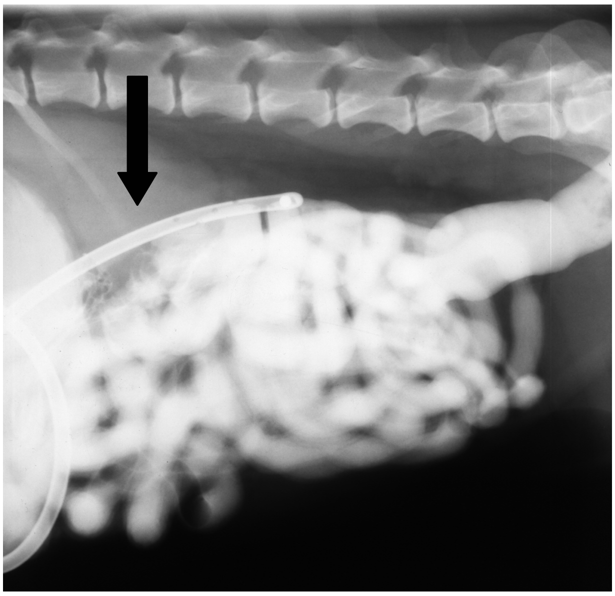


Fig.2.10 Enteroclysis examination. Lateral radiograph of the abdomen at the time of complete filling of the small intestinal loops (dog No.3). All intestinal loops are distended with the radiographic contrast material. Presence of contrast material in the stomach and in the colon is also evident. The plastic tube used for duodenal intubation can be seen on the left of the picture (black arrow).

Reflux examination

In one dog (dog No.1) propofol was used additionally to the medetomidine sedation, but this proved to be unnecessary in the other two dogs. The fluid infusion caused gradual distension of the colon and subsequently that of the entire intestinal tract. The infusion was stopped when the fluid column reached the descending duodenum. At that time, all of the intestinal loops were distended, showing fluid pattern with only a minimal amount of gas bubbles remaining in their lumen. Some fecal material also remained at the ileocaecal part despite of the previous enemas. Both small and large intestinal loops were completely filled with fluid and transiently paralyzed *(Fig.2.11-14)*. This technique had very little effect on the stomach as only small amount of reflux occurred during this study. The results of the initial scans and those of the scans following fluid administration together with the time needed for fluid administration are presented in *Table 2.3*.

Dog No.	**Fluid**	**Results of the initial scan**	**Image quality at time of complete filling**	**Time needed for complete filling**
3.	1300 ml saline	1-2 3 1	2-3 4 4	9 min.
5.	1300 ml saline	2-3 2-3 1	2-3 3 4	8 min.
6.	1300 ml saline	2-3 2-3 1	2-3 4-5 4-5	12 min.

Table 2.3 The results of the reflux examination. The number(s) in the cells indicate the grades given for the ultrasonographic quality of the stomach and proximal duodenum (top), the rest of the small intestines (middle) and the large intestines (bottom), respectively.

Ultrasonographic appearance of the gastrointestinal wall

The gastrointestinal wall had typical layered appearance during both the initial examinations and during the ultrasonography following any type of fluid administration. The number of visible layers depended on the frequency of the transducer used. With a 5 MHz transducer, generally only 3 layers were visible: an innermost thin echogenic layer representing the interface between mucosa and lumen, a thick echopoor one in the middle representing the combination of mucosa, submucosa and muscular layers, and an outer thin echogenic one representing subserosa, serosa. In some instances, when the visualization of the stomach wall was suitable (mucus or fluid content), the stomach wall was seen to consist of five layers: 3 echogenic layers and 2 echopoor ones in between them. With the use of 7 or 10 MHz transducers all intestinal segments had this 5 layers appearance. Generally, the innermost echopoor layer, representing the mucosa was the thickest one. However, following rapid fluid administration, in some dogs during the enteroclysis or reflux examination a transient increase in the thickness of the innermost echogenic layer, representing mucosal-lumen interface was noted (*Fig. 2.8 and 2.12*).

Fig 11. Reflux examination (dog No.6). The ultrasonographic image of the colon and the duodenum in sagittal view. The colon (top) is filled with anechoic fluid. The descending duodenum (under the colon) was used to monitor the retrograde filling of the intestines. A small amount of fluid can be also seen in the slightly dilated lumen of the duodenum.

Fig.2.12 Reflux examination (dog No.6). Ultrasonographic image of fluid filled small intestinal loops in transverse view. The intestinal lumen contains anechoic fluid. Note the prominent innermost hyperechoic layer of the bowel wall.

Fig.2.13. Reflux examination. Ultrasonographic image of the fluid filled ileocaecocolic junction in dog No.3. The fluid filled structure in the left part of the picture is the colon. The lumen of the caecum is also filled with anechoic fluid (white arrow), however the terminal part of the ileum contains hyperechoic content (black arrow).

Fig.2.14 Reflux examination (dog No.6). Ultrasonographic image of three fluid filled small intestinal loops in transverse view (top of the picture) and sagittal view of the colon (bottom of the picture). The layered structure of the wall of the small intestinal loops is recognizable. The fluid in the lumen of the intestines is anechoic.

DISCUSSION

Gas in the gastrointestinal tract represents by far the most common cause of an unsatisfactory abdominal ultrasound examination in both human and veterinary medicine. The disturbing effect of gas is due to its acoustic properties that largely differ from those of the abdominal organs. Replacing the gas by fluid has been suggested in upper gastrointestinal ultrasonographic examinations both in human and canine patients, and during ultrasonography of the rectum and colon in humans (Joharjy et al. 1990, Penninck et al. 1990, Limberg 1992, Nagita et al. 1994).

The aim of this study was to assess the effect of replacing gas in the gastrointestinal tract by fluid administration following three different routes, that have been used for radiographic contrast techniques.

During these experiments, I used tap water, soluble iodide contrast material, physiologic saline solution and carboxymethylcellulose (CMC) solution. The soluble iodide contrast was chosen for an immediate comparison between radiographic and sonographic contrast techniques. By using this agent during the SBFT study we were able to follow the aboral passage of contrast material both on the series of radiographs and during the repeated ultrasound examinations. The use of radiographic contrast also enabled me to check the complete filling of the small intestinal loops in the enteroclysis examination. The use of barium would have produced better radiographic images, but would have deteriorated the quality of the ultrasonographic images (Leopold and Asher 1971). Human investigations have described the superior image quality that was found when CMC solution was used as a sonographic contrast material instead of tap water (Lund et al. 1992, Sisler and Tilcock 1995). That is why I mainly used this agent during our experiments. One exception was the reflux study where the absorptive capacity of the colon had to be taken into consideration. I used physiologic saline solution, as this fluid has no effect on the serum electrolytes. The use of saline solution is also suggested in human hydrocolonic sonographic examinations (Nagita et al. 1994). I did not find differences in the sonographic image quality related to the use of different fluids. The poor image quality of the stomach of a dog, to which iodide contrast had been given, was probably due to the presence of large amounts of gas in the stomach, and not to the effect of the fluid itself. Small bubbles inside the fluid were noted both when CMC solution or iodide contrast were used, but their presence did not hamper the visualization of the gastrointestinal wall.

An ideal ultrasonographic technique would allow assessment of the gastrointestinal wall, as well as the lumen and the peristalsis of the whole gastrointestinal tract. Because unlike radiography, sonography lacks overview of the entire abdomen, the only way to be sure that the whole gastrointestinal tract is visualized is when it was possible to follow the intestines from the pylorus to the rectum or vice versa. None of the three sonographic contrast techniques has fulfilled all these criteria.

There was a positive relation between the distension of the lumen with fluid and the quality of the ultrasound images. The largest part of the gastrointestinal tract was filled with fluid during the reflux examination, when both the large and small intestines could be well visualized. Even though identification of more segments was possible than with the other techniques (i.e. both the rectum, the colon, the ileocaecal junction and the duodenum could be identified), I was not able to follow the whole intestinal tract from duodenum to colon. It was also impossible during the other methods. The enteroclysis technique caused distension of all of the small intestines and to a smaller extent the stomach and the colon. Unlike in the reflux examination, the large intestine was not cleaned with previous enemas in this study and as a result, the image quality of the large intestines was not acceptable. The fluid administration through a gastric tube caused distension of only the stomach and had much less effect on the intestinal tract. There were a few minutes delay during this study until improvement of the image of the stomach could be noted following fluid administration, and in one case, no improvement was noted at all until the stomach became completely empty. Both problems are related to the intraluminal gas that was most probably introduced by, or in the latter case, already present before the fluid application. Gas removal is suggested by Penninck et al. (1989), and lack of gas removal in our study may explain the unsatisfactory results.

Following administration of fluid to the stomach, there was a slight increase in peristaltic activity of the gastrointestinal tract, while the reflux and enteroclysis techniques hampered the study of peristalsis by causing transient paralysis of the intestines. As the assessment of peristalsis seems to be of special importance in the diagnosis of partial or complete obstruction, fluid administration may be of no use in the sonographic diagnosis of these disorders (Manczur et al. 1998). However, fluid administration may be valuable for the detection of small intramural or luminal lesions that cause only slight or no obstruction.

From a technical point of view, the administration of fluid through a gastric tube was the simplest technique to perform. Both the enteroclysis and the reflux techniques had the disadvantage that the dogs had to be sedated during the examination. The need of fluoroscopy and the difficulties of duodenal intubation put enteroclysis to the third place.

When considering time demand (both for preparation and examination time), the reflux technique was the fastest examination, while the SBFT study was the most time consuming method.

The use of smooth-muscle relaxant drugs are advocated in both per oral and per rectal fluid administration in humans (Joharjy et. al. 1990, Limberg 1992, Mittelstaedt 1992). Such drugs were not used in the present study, but medetomidine, that was used for sedation may have had a similar effect on the GI tract. Smooth muscle relaxant drugs may have a beneficial influence on the sonographic image of the stomach in case of per oral fluid administration, but both gastric emptying and peristaltic activity might be depressed by their use.

The gastrointestinal wall showed the typical layered appearance as described in the literature (Kimmey et al. 1989, Penninck et al. 1989, Wiersema and Wiersema 1993). Whether or not these layers were visible depended on the luminal content. When gastrointestinal segments with large amount of intraluminal gas were scanned, only the gastrointestinal wall towards the transducer could be imaged and the visibility of the layers of this part of the gastrointestinal wall were also poor. By the positional changes, described in the "materials and methods", the negative effect of small amount of gas could be avoided and the proximal wall was well visualized. In case of mucus or fluid content both the walls proximal and distal to the transducer could be assessed. The number of visible layers depended on the frequency of the transducer used. This is explained by the different resolution of the transducers. The gastric wall layers were better visualized, because physiologically the stomach wall is thicker than the wall of the rest of the gastrointestinal tract. The transient increase in the relative thickness of the innermost echogenic layer of the intestines in some dogs during rapid fluid administration was most probably due to entrapped microbubbles among the villi of the intestine, as this layer corresponds to the mucosal-luminal interface (Lim and Jeong 1994).

In conclusion of our study:

1. **I found the reflux examination to be the most promising sonographic contrast technique for the visualization of the small and large intestines. Because this technique causes paralysis of the intestines, the peristaltic activity should be assessed prior to this examination.**

2. **I was not able to systematically follow the whole intestinal tract from pylorus to rectum or vice versa, even when it was completely filled with fluid thus, a systematic scanning of the entire abdomen is required during ultrasonography of the gastrointestinal tract. If gas containing gastrointestinal segments are encountered, their negative effect can be avoided by positional changes and compression, similarly to non-contrast sonographic techniques.**

3. **The administration of fluid to the stomach has little effect on the image quality of the intestinal tract. Nevertheless, it is a useful technique for the examination of the stomach and proximal duodenum. Gas removal and application of smooth muscle relaxant drugs may improve the effectiveness of this technique.**

Acknowledgements

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CHAPTER III

SONOGRAPHIC DIAGNOSIS OF INTESTINAL OBSTRUCTION IN THE DOG

Partial or complete obstruction of the small intestine of the dog can be caused by indigestible foreign material, masses of parasites, postoperative adhesions, neoplasm, granulomas, abscesses, volvulus, intussusception and hernial incarceration. Paralysis of a segment or the entire small bowel caused by peritonitis, or enteritis, or pancreatitis, or certain drugs, or following laparotomy may cause signs of intestinal obstruction (Fraser, 1991). Moreover, intestinal paralysis can also be a result of a prolonged mechanical obstruction. Intestinal obstruction can be a surgical emergency, thus differentiating surgical cases from those that can be managed by means of conservative treatment is of primary importance when evaluating a dog with signs of ileus. The diagnosis is traditionally based on the physical findings and proven by plain film radiography. If the physical and radiographic findings are equivocal, repeated films are taken following the administration of a radiographic contrast material. The sensitivity of the contrast examination (upper gastrointestinal study) is low and enteroclysis has been proposed as a sensitive tool to diagnose those cases where the previous radiographic findings are inconclusive (Wolvekamp, 1989). However this latter technique requires the use of fluoroscopy, which is not readily available in veterinary medicine.

Ultrasonography has been used for many years to diagnose the disorders of various abdominal parenchymal organs in the dog. The sonographic appearance of the normal canine gastrointestinal tract and that of some gastrointestinal disorders have been also described (Penninck et al., 1989 and 1990). Reports on the sonographic appearance of canine intestinal ileus are limited to that of the gastrointestinal foreign bodies, invagination and paralytic ileus (Fluckiger and Arnold, 1986; Kantrowitz et al., 1988; Penninck et al., 1990; Watson et al., 1991; Tidwell and Penninck, 1992; Kramer and Gerwing, 1996). Numerous authors have described the sonographic findings of small intestinal obstruction in human beings. There are also sonographic criteria for the diagnosis of this disorder in humans (Ko et al., 1993; Ogata et al., 1994 and 1996; Truong et al. 1992). The aim of this paper was to establish similar sonographic criteria, and evaluate their efficacy in the diagnosis of intestinal obstruction of the dog.

MATERIALS AND METHODS

Between May 1, 1996 and April 30 1997, all dogs that were presented to the Department and Clinic of Internal Medicine at the University of Veterinary Science Budapest, and were determined to have possible small bowel obstruction on the basis of the clinical examination, were candidates for this study. Patients with the signs of intestinal obstruction (vomiting, abdominal pain, abnormal abdominal palpatory findings, changes in defecation) were entered into this study only when a sonographer experienced in the technique of intestinal imaging was available at the time of the patient evaluation. The dogs underwent abdominal ultrasonography as part of their routine diagnostic work up using commercially available ultrasound scanners equipped with 3.2, 5 or 7 MHz sector transducers (Brüel & Kjaer 1846 and Brüel & Kjaer Panther 2002, Naerum, Denmark). No particular preparation was given to the dogs other than clipping the hair from the ventral abdomen, and application of ultrasound gel. The interference by gas echoes from the bowels was avoided by changing the dogs' position and scanning from different planes as described by Penninck (1989). Sonographic findings were recorded on VHS videotape during the scanning, and the reports were stored in a computerized patient data system immediately after the examination. In the sonographic report particular attention was paid to the presence of intestinal obstruction. The sonographic diagnosis was established by using previously determined criteria based on the author's former experience. These criteria for small intestinal obstruction were: 1.) the presence of one or more fluid filled small intestinal loop(s) with unsuccessful peristaltic activity, observed as a pendulous, i.e. "to-and fro" movement of the intestinal ingesta, or 2.) the presence of invaginated intestinal loops or a foreign body which transmits the ultrasound beam in the distended bowel, or 3.) distended small intestinal loops with non-uniform peristaltic activity (both increased and decreased), or 4.) the presence of akinetic intestinal loops together with free abdominal fluid accumulation in the abdomen. If any of these signs was present, sonographic diagnosis of intestinal obstruction was made *(Fig. 3.1 and 3.2)*.

Fig. 3.1 Cross sectional ultrasound image of invaginated intestinal loops in a dog. The outer circle represents the intussuscipiens, the inner circle the intusseptum, between the two the entrapped mesentery and dilated vessels are also visible.

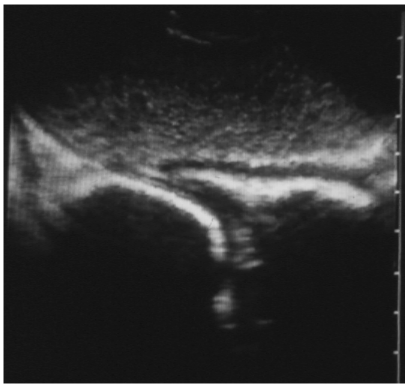

Fig. 3.2 Ultrasound image of a dilated fluid filled intestine in longitudinal and two gas filled ones in cross section. Pendulous movement of the ingesta was observed in the fluid filled intestine during the examination. Ultrasound diagnosis was intestinal obstruction.

The sonographic criteria for paralytic ileus were the observation of fluid filled intestinal loops with decreased or no peristaltic activity, and without the above mentioned signs of an obstruction *(Fig. 3.3)*.

When examining a dog with non-distended intestines, or with moderately distended intestines and uniformly increased peristalsis, we considered the case not having any forms of ileus.

Fig. 3.3. Dilated fluid filled intestines in a dog. No peristalsis was visible during the examination. Ultrasound diagnosis was paralytic ileus.

In all dogs where sonographic signs of intestinal obstruction were present, abdominal surgery was performed. In dogs with paralytic ileus, or without the sonographic signs of ileus, laparotomy was performed only if other investigations (radiography) indicated long standing obstruction or perforation. The final diagnosis was established by the result of surgery, post mortem examination, or the clinical outcome of the case. The sonographic findings were compared with the final diagnoses in order to determine the sensitivity, specificity, positive and negative predictive value of the above mentioned criteria (Rijnberg, 1995).

RESULTS

There were 44 dogs, (23 male, 21 female) with signs of small intestinal obstruction entered in this study. They ranged in age from 3 months to 15,5 years (mean 4 years old).

Of the 15 dogs underwent abdominal surgery, 13 had the final diagnosis of complete or incomplete obstruction. Among the other two dogs without obstruction, one had paralytic ileus, and one had intestinal perforation.

The remaining 29 cases were treated conservatively and the diagnoses were established by the clinical or post mortem examination results.

The final diagnoses and the ultrasonographic findings of the 44 cases are summarized in *Table 3.1*.

Final diagnosis	**No. of cases**	**Ultrasound findings**					
		"to and fro" movement of the ingesta	invagination or visible foreign body	non-uniform peristaltic activity	paralytic ileus and free fluid accumulation in the abdomen	paralytic ileus	non-distended intestines
Intestinal obstruction was present	**13**	**6**	**2**	**1**	**2**	**1**	**1**
ingested foreign bodies	**8**	6			1*	1	
Invagination	**2**		2				
intestinal adhesion	**1**						1
intestinal volvulus	**1**				1		
intestinal tumor	**1**			1			
Intestinal obstruction was not present	**31**	**2**	**-**	**-**	**-**	**12**	**17**
enteritis (incl. Parvoviral enteritis)	**17**					10	7
pancreatitis-pancreas tumor	**4****					1	3
Obstipation	**3**	1					2
Inflammation with intestinal perforation	**1**					1	
disorders of other organs (e.g. renal insufficiency)	**6****	1					5
Total number of cases	**44**	**8**	**2**	**1**	**2**	**13**	**18**

Table 3.1 The final diagnoses and the ultrasound findings of the examined 44 cases.
*: In this case, an ingested foreign body caused intestinal perforation and septic effusion. **: The structural changes in the pancreas and other abdominal organs (liver, kidneys) could be readily detected by ultrasonography during the examination.

Ultrasound findings

The wall, luminal diameter, luminal content and peristaltic activity of the small intestines could be evaluated in all 44 dogs. The sonographic findings could be classified in the following 6 groups.

1) Dilated intestinal loops with pendulous movement of the ingesta were seen in 8 cases (18 %) and these cases were diagnosed sonographically as obstructive ileus. This sign was observed as "to and fro" movement of the echogenic gas bubbles and food particles in the dilated intestinal lumen together with the contraction of the intestinal wall. Among the 8 patients, 6 had complete intestinal obstruction. In one of the remaining two dogs, severe obstipation was diagnosed by radiography and this patient was treated conservatively. Paralytic ileus was diagnosed in the other cases during the subsequent operation.

2) In two cases (5 %), the typical sonographic signs of invagination were present (i.e. multi-layered appearance of the bowel, concentric rings sign) and the diagnosis was proven by laparotomy in both dogs.

3) Dilated intestines with various degree of peristaltic activity (some loops with increased, while others with decreased peristalsis) were seen in one dog (2 %), which was diagnosed during laparotomy to be an incomplete ileus caused by an intramural neoplastic process.

4) Sonographic signs of paralytic ileus together with abdominal fluid accumulation were found in two dogs (5 %). Surgery revealed intestinal volvulus in one of them, and an intestinal perforation caused by an ingested foreign body in the other dog.

5) Local or generalized paralytic ileus were found in 13 cases (30 %). Among them, 10 dogs had moderate to severe enteritis, one dog had a pancreatic tumor, one dog had long standing complete obstruction and one dog had small intestinal perforation caused by a septic inflammation of the intestinal wall.

6) In 18 cases (41 %) nondistended, or only moderately distended bowels were found together with normal or slightly increased peristalsis during the ultrasound examination. All of the dogs but one had either mild enteritis, or pancreatitis, or obstipation, or organic dysfunction of other abdominal organs and were treated conservatively. The remaining dog was found to have a chronic intestinal adhesion by laparotomy.

Obstruction was correctly diagnosed by ultrasonography in 11 of the 13 dogs with mechanical ileus, and was correctly disclosed in 29 of the 31 non-obstructive cases. Thus, the previously described sonographic criteria had 85 % sensitivity and positive predictive value, and 94 % specificity and negative predictive value. The comparison of the final diagnoses and the ultrasound results, together with the sensitivity, specificity, positive and negative predictive values of ultrasonography are shown in *Table 3.2*.

Ultrasound diagnosis	Intestinal obstruction was present	Intestinal obstruction was not present	Sensitivity	Specificity	Positive predictive value	Negative predictive value
Obstruction -------------- **No signs of obstruction**	**11 of 13 (TP)** -------------- **2 of 13 (FN)**	**2 of 31 (FP)** -------------- **29 of 31 (TN)**	**85 %**	**94 %**	**85 %**	**94 %**

Table 3.2 Comparison of the ultrasonographic and the final diagnoses in determination whether intestinal obstruction was present. The ultrasound diagnosis was based on the observation of the signs that are listed in *Table 3.1*.
TP= true positive cases, FP= false positive cases, TN= true negative cases, FN= false negative cases
Sensitivity is calculated as TP/TP+FN, and specificity is calculated as TN/TN+FP.
Positive predictive value is calculated as TP/TP+FP, and negative predictive value is calculated as TN/TN+FN.

DISCUSSION

Human studies have proven the value of ultrasonography in the diagnosis and management of different forms of ileus (mechanical and paralytic) in human beings (Truong et al., 1992; Ko et al., 1993; Ogata et al., 1994 and 1996). The criteria that are used in human medicine for bowel obstruction are based on the observation of a distended bowel proximal to a non-distended one, and observation of peristaltic activity in the distended proximal bowels (Ko et al., 1993; Ogata et al., 1994 and 1996). Human investigators also mention the "to and fro" movement of the ingesta inside the dilated intestinal loops proximal to the site of the obstruction (Ogata et al., 1994 and 1996). Recently, duplex Doppler technique has also been proposed to observe the altered peristaltic movement of the ingesta in the obstructed bowel in human cases (Gimondo et al., 1995).

Not all of these criteria can be applied to veterinary medicine, because differentiating between the different small intestinal loops is not possible (Penninck et al., 1989). Among the sonographic signs of ileus in the dog, paralytic ileus has been described (Penninck et al., 1990). The description of the sonographic picture of invaginated intestines and foreign bodies are also known from the veterinary literature (Fluckiger and Arnold, 1986; Kantrowitz et al., 1988; Watson et al., 1991; Tidwell and Penninck, 1992; Kramer and Gerwing, 1996). In one article, Tidwell and Penninck (1992) mention other sonographic signs of mechanical ileus that were seen in dogs with ingested foreign bodies (increased peristaltic activity, ascites, lymphadenopathy and pancreatitis). However, no study was done to evaluate the value of the observation of these signs in the diagnosis of mechanical ileus in the dog.

Two veterinary articles have described the sonographic image of gastrointestinal foreign bodies (Tidwell and Penninck, 1992; Kramer and Gerwing, 1996). During my study I have not found any ingested foreign body that transmitted the ultrasound beam. They were also rarely encountered outside this study period. This finding is in accordance with Kramer and Gerwing (1996), who have seen foreign bodies only in half of their reported cases. The echogenic reflex (caused by foreign materials that reflect the ultrasound) and the acoustic shadowing (caused by reflection and/or absorption of the ultrasound beam) were seen in some of our foreign body ileus cases. According to Tidwell and Penninck (1992), the acoustic shadowing of a foreign body can be differentiated from the shadowing of intraluminal gas by the lack of internal echoes inside it. My previous experience, however, did not prove the reliability of this sign in differentiating foreign bodies from gas accumulation inside the bowel lumen, and this fact was also mentioned by Tidwell and Penninck (1992). Thus, I did not include this sign among the sonographic criteria for diagnosing intestinal obstruction. I also did not include the measurements of the luminal diameter of the dilated intestinal loops, because, I believe that these data themselves do not help to differentiate between mechanical obstruction and paralytic ileus.

In this study I tried to establish and evaluate sonographic criteria for gastrointestinal obstruction in the dog, by using four different sonographic signs to diagnose intestinal obstruction.

1.) The first established criterion was the observation of pendulous movement of the ingesta. This can be explained by the increased peristaltic activity of the obstructed bowel that tries to move the intraluminal content of the intestine to aboral direction, but the ingesta is reflected back from the site of the obstruction. I expected this sign to be very sensitive for foreign body ileus and the results of this study have proven my expectations, (6 of 8 dogs showed this sign). Long standing obstruction had caused paralysis in two cases, which explains why it was not possible to find this sign in those dogs. In addition, there where pendulous movement of the ingesta in two dogs without small bowel obstruction. In one of them, this movement was seen in only one intestinal loop and may be explained by the severe obstipation in the colon that could have mimicked the sign of obstruction in the ileum or distal jejunum. In the other dog, no reason was found for the observation of this sign, as only paralytic bowels were found during surgery. It is necessary to call the attention here for the fact, that the pendulous movement of ingesta may be mistaken for the passive flowing movement of fluid inside a paralytic intestine or colon. This passive "to and fro" flow is caused by the respiratory movements of the animal, and not by peristaltic activity, therefore swirling movement of echogenic spots in the ingesta or intestinal wall contractions can not be observed in those cases. Duplex Doppler ultrasonography may be also useful to differentiate between the two forms of ingesta movement but it has not been applied to canine patients, yet.

2.) Before this study period, I sometimes encountered dogs, where dilated intestinal loops with both increased and decreased peristaltic activity could be observed during ultrasonography. Those dogs suffered from incomplete obstruction. That is why this sign was included among the criteria. During this study, this sign was observed in one case, and laparotomy revealed an intestinal tumor causing incomplete obstruction. Intestinal tumors can be readily detected ultrasonographically as thickening and disruption of the layered appearance of the intestinal wall (Penninck et al., 1990). No wall thickening was detected in this case, which may be explained by the gas accumulation in some of the intestinal loops that prevented visualization of the affected part of the gastrointestinal tract.

3.) The sonographic appearance of invaginated intestinal loops has been described as intestine in intestine, hayfork sign, concentric rings sign, multi-layered appearance of the bowel etc. (Fluckiger and Arnold, 1986; Kantrowitz et al., 1988; Penninck et al., 1990; Watson et al., 1991). The known high sensitivity of ultrasonography for detecting invagination has been demonstrated in two dogs during the present study.

4.) Finally, I also included among the criteria the observation of paralytic intestines together with abdominal fluid accumulation. This criterion was brought from human studies where it proved to be a sensitive indicator for strangulation (Ogata et al., 1994 and 1996). In the two dogs where I observed these alterations, one of them had intestinal volvulus, and the other had an ingested foreign body that caused mechanical obstruction, perforation and septic effusion.

Similarly to previous human reports, the diagnostic values (sensitivity, specificity, positive and negative predictive values) of ultrasonography were also high in the present study. This indicates that ultrasonography may have an important role in the diagnosis of small intestinal obstruction of the dog. By using the above mentioned criteria it is possible to reliably diagnose or disclose intestinal obstruction in the majority of the cases. The decision of the treatment (surgery versus conservative) should be the result of both ultrasonography and the clinical examination. This approach is of special importance when paralytic ileus is found during the ultrasound examination, as this condition may be also caused by a long standing obstruction. Comparison of ultrasonography and plain film radiography would be important to better evaluate the role of ultrasonography among the other imaging modalities in the diagnostic process of canine ileus.

From the result of the present study it can be concluded that:

1. **The observation any of the following ultrasonographic signs can be used to diagnose intestinal obstruction in the dog:**

the presence of one or more fluid filled small intestinal loop(s) with unsuccessful peristaltic activity, observed as a pendulous, i.e. "to-and fro" movement of the intestinal ingesta, or

the presence of invaginated intestinal loops or a foreign body which transmits the ultrasound beam in the distended bowel, or

distended small intestinal loops with non-uniform peristaltic activity (both increased and decreased), or

the presence of akinetic intestinal loops together with free abdominal fluid accumulation in the abdomen.

2. **Ultrasonography is a valuable diagnostic technique in the diagnosis of canine intestinal obstruction.**

This study has been published as follows:

Manczur, F., Vörös, K., Vrabély, T., Wladár, S., Németh, T. and Fenyves, B. (1998): Sonographic diagnosis of intestinal obstruction in the dog. Acta Vet. Hung. **46**, 35-45.

CHAPTER IV

COMPARISON OF ULTRASONOGRAPHY AND SURVEY RADIOGRAPHY IN INTESTINAL OBSTRUCTION OF THE DOG: A RETROSPECTIVE STUDY OF 45 CASES

Ileus - dilation of the intestines and ceasing of intestinal passage - is a common gastroenterological disorder in dogs. Intestines can be distended with gas, fluid or both. Ileus can be mechanical or functional. Mechanical or dynamic ileus is caused by luminal obstruction, whereas functional or adynamic ileus is due to inhibition of intestinal smooth muscle tone. Intestinal obstruction can be caused by intraluminal objects, thickening of the intestinal wall, or extramural compression. Functional ileus can be a result of inflammation (enteritis, peritonitis or vasculitis), former operation, electrolyte imbalance, spinal trauma, thrombosis, prolonged mechanical obstruction, or drug administration (Willard 1992). A special type of functional ileus, called chronic pseudo-obstruction syndrome, has also been reported. This intestinal motility disorder is caused by damage to intestinal smooth muscle, degeneration of myenteric plexus, fibrosis of the intestinal wall or occur in the absence of structural abnormalities (Willard 1992, Lamb and France 1994). Successful management of different forms of ileus is based on the correct identification of the cause, and the first step in this process is the exclusion of the possibility of mechanical obstruction. The diagnosis of intestinal obstruction is based on the history and the result of the physical examination and then traditionally confirmed by radiography. If survey radiographs are not diagnostic, repeated films can be taken after administration of a radiographic contrast material. Recently, ultrasonography has been suggested to be used for the diagnosis of intestinal obstruction both in humans and in different animal species. The technique of the examination and the presenting signs have been also described (Meiser and Meissner 1987, Penninck et al. 1990, Truong et al. 1992, Ko et al. 1993, Ogata et al. 1994 and 1996, Braun et al. 1995, Czechowski 1996, Klohnen et al. 1996, Manczur et al. 1998). The aim of this paper was to compare the diagnostic value of ultrasonography with that of routine plain film radiography in the diagnosis of intestinal obstruction of the dog.

MATERIALS AND METHODS

Since 1995, ultrasonography has been routinely used at our institution in the diagnostic workup of gastroenterological disorders of dogs. Data of dogs presented at our clinic between 1 May 1996 and 30 April 1998 and determined to have possible small bowel obstruction on the basis of the clinical examination were analyzed. Those patients that underwent both plain film abdominal radiography and abdominal ultrasonography within 24 hours were selected for this retrospective study. To minimize the error that may be caused by personnel subjectivity only dogs that were examined by the same sonographer (FM) during the initial examination were included. For the same reason, radiographs were re-evaluated by the same radiologist (BF). Examinations were performed on conscious dogs without any particular preparation, however hair was clipped from, and coupling gel was applied onto the ventral abdomen before ultrasonography. Abdominal ultrasonography was performed using ultrasound scanners equipped with a 3.5 MHz, a 5 MHz and a 7 MHz convex mechanical transducers and a 3.5-5 MHz multifrequency electronic convex transducer (Brüel & Kjaer 1846 and Brüel & Kjaer Panther 2002, Naerum, Denmark). The dogs were held in left lateral, dorsal and oblique (between left lateral and dorsal) recumbency during ultrasonography. Scanning from dependent side of the abdomen and slight increase of pressure with the transducer were often applied to avoid the disturbing effects of intraluminal gas and to displace superficial gas containing intestinal loops. Radiography was performed using conventional radiographic equipment (United States, Eureka) and film intensifying screen. The dogs were held in lateral recumbency. Films were developed by automatic developing equipment (Protec 35, Compact, Germany). Radiography was considered to be positive if grossly and unevenly dilated intestinal loops or a radiopaque foreign material inside the intestinal lumen was seen on the films *(Fig. 4.1).* In the absence of intestinal dilatation or when evenly dilated intestinal tract was seen, radiography was stated to be non-confirmatory to diagnose intestinal obstruction (negative finding). Following the subjective assessment of the radiographs, the fifth lumbar vertebral body height (L5) and the largest small intestinal diameter (SI) were also measured. A SI/L5 ratio larger than 1.6 was considered to be indicative of intestinal obstruction (Graham et al. 1998).

The ultrasonographic diagnosis of intestinal obstruction was based on formerly established and published criteria (Manczur et al. 1998). These criteria included the observation any of the following features:

1. pendulous (“to and fro”) movement of ingesta inside one or more intestinal segments caused by active peristaltic contractions *(Fig.4.2)*,
2. invaginated intestinal loops or an ingested foreign body that transmits the ultrasound,
3. simultaneous observation of intestinal segments with both decreased and increased peristalsis,
4. paralytic intestines and free fluid accumulation in the abdominal cavity.

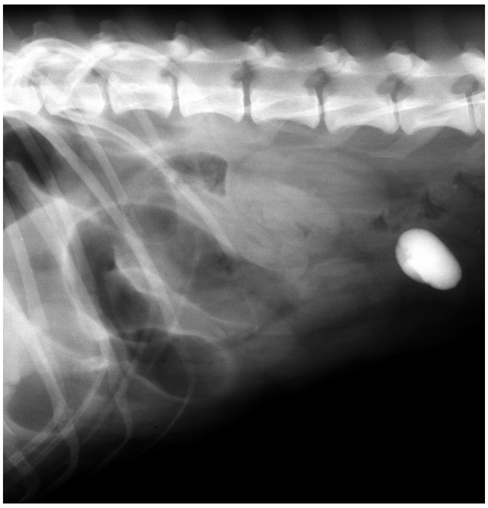

Fig.4.1 Lateral abdominal radiograph of a dog with mechanical ileus. The visible radiographic changes (markedly dilated intestinal loops, radiopaque foreign body) are typical radiographic features of intestinal obstruction.

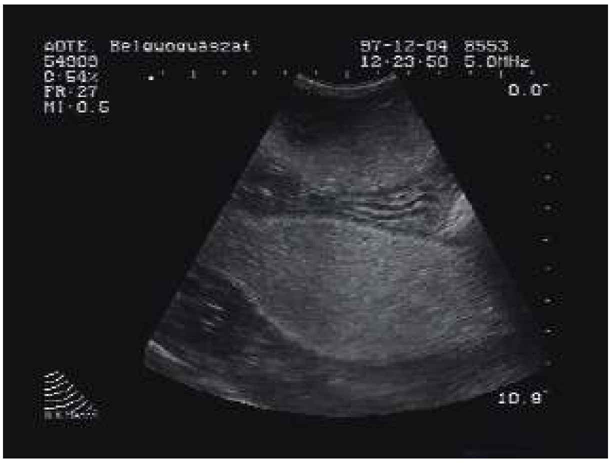

Fig.4.2 Sagittal ultra-sonographic image of dilated intestinal loops together with a collapsed bowel (white arrow). Increased peristaltic contractions of the dilated intestines and pendulous movement of the intraluminal ingesta were seen during ultrasonography. This ultrasonographic changes are generally associated with intestinal obstruction.

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Fig.4.3 Ultrasonographic image of dilated, fluid filled intestines. No peristalsis were observed during the examination. These ultrasonographic findings are suggestive of paralytic ileus.

In the absence of intestinal dilatation or when paralytic intestinal tract (without fluid in the abdomen) was observed only, ultrasonographic findings were considered to be negative *(Fig. 4.3)*. Final diagnosis was determined on the basis of the result of surgery, post mortem examination or the clinical outcome of the case. Dogs with gastric foreign bodies or with intestinal perforation without evidence of gastric outflow or intestinal obstruction were not considered as mechanical ileus cases.

The results of ultrasonography and radiography were compared with the final diagnosis to compare the diagnostic values of the two imaging methods. Sensitivity was calculated as true positive cases per true positive- plus false negative cases, and specificity was calculated as true negative cases per true negative- plus false positive cases. Positive predictive value was calculated as true positive cases per true positive and false positive cases, and negative predictive value was calculated as true negative cases per true negative and false negative cases (Rijnberk 1995).

RESULTS

The results of 46 ultrasonographic and 45 radiographic examinations of 45 dogs were compared. There were 27 males and 18 females, and their age ranged from 3 month to 15,5 year (mean 4,6 year). 16 dogs were operated, whilst in the other 29 cases the final diagnoses were determined from post mortem examination or from the clinical outcome of the case. 11 dogs had intestinal obstruction and 34 animals suffered from other diseases that caused no obstruction. The final diagnoses and the results of the two imaging methods are summarized in *Table 4.1*.

Final diagnosis		**Sonographic signs of intestinal obstruction**	**Without sonographic signs of intestinal obstruction**	**Radiographic signs of intestinal obstruction**	**Without radiographic signs of intestinal obstruction**
Intestinal obstruction	**11**	**8**	**3**	**10**	**1**
ingested foreign body	7	5	2	6	1
adhesion	2	1	1	2	0
intestinal volvulus	1	1	0	1	0
intestinal tumor	1	1	0	1	0
No intestinal obstruction	**34**	**3***	**32***	**9**	**25**
gastritis, gastroenteritis, incl. parvoviral enteritis	16	0	16	2	14
pancreatitis	3	0	3	0	3
intestinal perforation	3	1	2	3	0
renal insufficiency	3	0	3	0	3
obstipation	3	1	2	1	2
postoperative paralysis	2	0	2	2	0
leptospirosis (hepatopathy)	1	0	1	0	1
panarteritis	1	0	1	0	1
sepsis	1	1*	1*	0	1
nonobstructive foreign body in the stomach	1	0	1	1	0

Table 4.1 Comparison of the results of ultrasonography and plain film radiography with the final diagnoses. *: One dog had two ultrasound examinations within 24 hours of plain film radiography. Because, the results of sonography were different, both results are included.

Ultrasonography correctly diagnosed intestinal obstruction in 8 of the 11 dogs with mechanical ileus, while correctly excluded the possibility of obstruction in 32 of the 34 dogs without intestinal obstruction. Radiography correctly diagnosed intestinal obstruction in 10 of the 11 cases, while correctly excluded mechanical ileus in 25 of the 34 cases. The sensitivity and specificity of ultrasonography in the diagnosis of small bowel obstruction were 73 % and 91 %, respectively, whereas those for plain film radiography were 91 %, and 74 %, respectively. The predictive value of ultrasonography for a positive result was 73 %, while that of radiography was 53 %. The predictive values for a negative finding of ultrasonography and radiography were 91 and 96 %, respectively.

Measurements of the fifth lumbar vertebral body and the maximum diameter of the small intestinal lumen were possible on 29 radiographs (64%). Lack of abdominal detail due to the presence of free abdominal fluid or superposition of fluid filled intestines, faces content of the large intestine, incorrect position of the dog were the most frequent reasons, why the measurements could not be performed in all cases. SI/L5 ratio of less than 1.6 was found in 20 unobstructed cases, while a ratio of more than 1.6 was found in 7 cases with and in 2 cases without obstruction. The two false positive cases (in both of them the ratio was 1.7) were a dog with intestinal perforation and another one with pancreatitis. The combined use of subjective assessment and evaluation of SI/L5 ratio increased the specificity, positive and negative value of radiography to 85%, 67% and 97%, respectively.

Abdominal surgery was indicated in 15 dogs and performed in 14 cases (in all the 11 dogs with intestinal obstruction and in further 3 dogs with intestinal perforation), while one dog with a gastric foreign body was successfully treated conservatively. Two dogs were operated with possible intestinal obstruction, but paralytic ileus in one of them, and splenomegaly, prostatic hypertrophy and obstipation in the other dog were the only abnormalities found during surgery. The use of ultrasonography itself correctly indicated surgery in 9 of the 15 dogs with 2 false positive results, while radiography alone was correctly indicating surgery in 14 of the 15 cases with 5 false positive results.

Among the changes observed during ultrasonography, unsuccessful peristalsis ("to and fro" movement of the luminal content) were observed in 6 dogs with mechanical ileus and in 2 animals without intestinal obstruction (paralytic ileus, obstipation). Simultaneous observation of intestinal loops with increased and decreased peristalsis were seen in one dog with intestinal tumor. Two dogs were observed with paralytic intestinal tract and fluid in the abdomen: one of them had intestinal volvulus, while the other had intestinal perforation. Three cases of intestinal obstructions were missed by the use of the above mentioned ultrasonographic criteria during this study: in two dogs localized paralysis of the intestinal loops, while in the third case generalized paralysis of the intestines were found during ultrasonography. The observed ultrasonographic alterations and the final diagnoses are compared in *Table 4.2*.

Gastrointestinal ultrasound findings	**Number of cases**	**Number and cause of intestinal obstruction**	**Number and final diagnoses of non-obstructive disorders**
Pendulous movement of intraluminal content, caused by active peristaltic contractions	8	5 ingested foreign body 1 adhesion	1 obstipation 1 paralytic ileus due to sepsis
Simultaneous observations of intestinal loops with different peristaltic activity	1	1 intestinal tumor	
Paralytic intestines and fluid accumulation in the abdomen	2	1 intestinal volvulus	1 intestinal perforation
Invaginated intestines or sonolucent foreign bodies	0		
Generalized decrease in intestinal peristalsis	12	1 prolonged mechanical obstruction due to ingested foreign body	9 gastroenteritis 1 paralytic ileus (sepsis) 1 intestinal perforation
Akinetic intestinal loop(s)	2	1 adhesion 1 ingested foreign body	
Increased peristalsis	1		1 gastroenteritis
Normal luminal diameter and peristalsis of the intestines with various degree of intraluminal gas accumulation	11		5 gastroenteritis 2 postoperative examination 1 obstipation 1 leptospirosis 1 gastric foreign body 1 renal insufficiency
Fluid filled stomach	3		1 gastritis 1 renal insufficiency 1 intestinal perforation
Thickened gastric wall	3		1 renal insufficiency 1 panarteritis 1 obstipation
Changes within the pancreas and secondary sonographic findings of pancreatitis	3		3 pancreatitis

Table 4.2 Ultrasonographic alterations of the gastrointestinal tract and the final diagnoses. The ultrasound results were simplified in order to fit into this table. Many of the dogs had more than one ultrasonographic alterations, but only the most prominent changes of their gastrointestinal tract are mentioned in the table. Changes in the appearance of abdominal parenchymal organs (e.g. liver, kidneys), although readily observed during ultrasonography, are also not included here.

DISCUSSION

Human clinical studies found ultrasonography to be a useful diagnostic technique in the differential diagnosis of different forms of ileus (Meiser and Meissner 1987, Truong et al. 1992, Ogata et al. 1994). A prospective study regarded ultrasonography to be as sensitive and more specific than plain film radiography in the diagnosis of bowel obstruction of humans (Ogata et al. 1996). Others reported the sensitivity of ultrasonography higher than conventional radiography in diagnosing small bowel obstruction and strangulation (Ko et al. 1993, Czechowski 1996). In the previous chapter I also demonstrated the value of ultrasonography in the diagnosis of intestinal obstruction of the dog (Manczur et al. 1998).

In this retrospective evaluation, ultrasonography proved to be less sensitive and more specific than radiography to diagnose intestinal obstruction. The chosen ultrasonographic criteria had similar sensitivity and specificity to our earlier published data (Manczur et al. 1998).

Dogs with invaginations or with a foreign body that transmits the ultrasound were not present in this study, because there were no dogs with these disorders where simultaneously performed radiographs and sonograms would have been available during the chosen time period. Ultrasonography is a widely used technique to diagnose invaginations both in humans and animals and has higher sensitivity and specificity than plain film radiography (Lamb and Mantis 1994, Stanley et al. 1997). The appearance of gastrointestinal foreign bodies has been also described (Tidwell and Penninck 1992, Kramer and Gerwing 1996). Direct visualization of intraluminal foreign bodies, however are uncommon ultrasonographic findings to my experience.

Among the other sonographic signs of intestinal obstruction, I observed the pendulous “to and fro” movement of the ingesta most frequently during and outside this study period (Manczur et al 1998). This sign can be explained by the forceful contractions of the intestinal tract during the early course of intestinal obstruction. Care should be taken to distinguish this sign from the passive “to and fro” flowing of ingesta as observed in paralytic intestines due to the respiration of the animal. Observing the swirling movement of echogenic intraluminal particles and the peristaltic movements of the intestinal wall in case of obstruction helps in differentiating between these two phenomena. Doppler ultrasonography has been reported to be useful in examining the movements of the intraluminal material during obstruction in humans, however no similar report exist in veterinary medicine to our knowledge (Gimondo et al. 1995).

The major disadvantage of ultrasonography is that it is unable to differentiate between paralytic ileus caused by prolonged mechanical obstruction or by other disorders. Nevertheless, localized paralysis of some intestinal loops may be a sonographic sign of mechanical ileus, as this sign was found in two dogs with intestinal obstruction during this study. This seems to be a similar finding to the simultaneous observation of different peristalsis along the intestinal tract in one of our cases with partial obstruction. Care should be taken to distinguish a dilated intestinal loop from the descending duodenum, which is often dilated in case of pancreatitis or ulceration. Similarly, localized paralysis of the small intestine may be mistaken with the fluid filled colon where peristalsis normally can not be observed (Penninck et al. 1990).

Simultaneous observation of fluid accumulation in the abdomen and paralytic ileus may be associated with intestinal strangulation or with peritonitis to our experience. Strangulation and peritonitis may be differentiated from each other by the quantitative estimation of free abdominal fluid during repeated sonographic examinations, as intestinal strangulation causes rapid fluid accumulation as reported in humans (Ogata et al. 1994). Strangulation also elicits prominent radiographic changes, thus combined use of ultrasonography and radiography may be more rewarding than repeated sonographic examinations.

The successful combination of radiography and ultrasonography was demonstrated in the present study, where all cases that required surgery were correctly diagnosed and only two unnecessary operation were performed.

The application of bowel diameter measurements increased the accuracy of radiography. Further studies are needed to evaluate ultrasonographic bowel diameter measurements and Doppler signs as possible objective criteria of intestinal obstruction of the dog. A promising recent study on rats found ultrasonography to be more accurate than radiography in diagnosing intestinal obstruction when those objective ultrasound criteria were used (Berlin et al. 1998).

In conclusion of the present study:

1. Ultrasonography proved to be less sensitive and more specific than plain film radiography in diagnosing intestinal obstruction of the dog.

2. Further studies are required to evaluate the observation of an akinetic intestinal loop (other than colon or descending duodenum) as another possible sonographic sign of intestinal obstruction.

3. The diagnostic value of radiography was increased by using more objective criteria. A similar approach in ultrasonography using bowel measurements and Doppler signs may have similar effect on the diagnostic value of ultrasonography.

4. The combination of plain film radiography and ultrasonography resulted in very accurate decisions about the need of surgical interventions of dogs with signs of ileus.

CHAPTER V

GASTROINTESTINAL ULTRASONOGRAPHY OF THE DOG: A REVIEW OF 265 CASES (1996-1998)

There is increasing use of ultrasonography during the diagnosis of various gastrointestinal disorders both in human and veterinary medicine (Mittelstaedt 1992, Penninck 1995, Lamb 1999). The normal ultrasonographic appearance and wall thickness of the intestinal tract of the dog has been described (Penninck et al. 1989). Changes in the thickness and appearance of the gastrointestinal wall, in the diameter and content of the gastrointestinal lumen and in the peristalsis can all be associated with pathological processes (Penninck et al. 1990).

The objectives of this retrospective study were to observe and assess these ultrasonographic alterations in a large number of clinical cases in order to determine the diagnostic value of these signs and thus, that of ultrasonography in the diagnosis of canine gastroenterological diseases.

MATERIALS AND METHODS

Data of the dogs with possible signs of gastrointestinal disorder that were examined ultrasonographically by me between May 1 1996 and April 30 1998 were analyzed. The indications for ultrasonography were vomiting, chronic diarrhea, abdominal pain, rectal bleeding, palpable mass in the abdomen and chronic weight loss. Dogs were examined with ultrasound scanners equipped with a 3.5-5MHz convex array and a 7 MHz sector transducer (Brüel & Kjaer 1846 and Brüel & Kjaer Panther 2002, Naerum, Denmark).

The abdominal skin was prepared as for a routine abdominal ultrasound examination (clipping of the hair, wetting with ultrasound gel.) All ultrasonographic examinations were performed on conscious dogs in dorsal and right lateral recumbency. When the pylorus and the proximal part of the duodenum could not be identified using this approach, the dogs were positioned oblique between dorsal and right lateral recumbency. When gas containing parts of the gastrointestinal tract interfered with the transmission of ultrasound, scanning from the dependent side of abdomen was tried. Often a slight increase of pressure with the transducer was used to displace superficial, gas containing intestinal loops.

RESULTS

Among the approximately 300 examined dogs, those 265 were selected into this study where the final diagnosis could be established from post mortem examination, histological examination, result of surgery or from the clinical outcome of the case. There were 154 males and 111 females within this population. 53 of them were mixed breed dogs, while the other 212 dogs belonged to 52 different pedigree breeds. Their age ranged from 2 months to 16 years (mean 5.1 years).

The animals were classified in 8 groups according to their final diagnosis.

1. Inflammatory conditions

163 dogs had gastrointestinal symptoms caused by various primary *(Fig.5.1)* or secondary (e.g. as a result of uremia) inflammatory disorders of some segments of the gastrointestinal tract (excluding the pancreas), maldigestion, constipation, pharyngeal or esophageal foreign body, megaesophagus, drug induced or postoperative motility disorder or non-gastrointestinal disease (e.g. pyometra, septicemia). The ultrasonographic findings are listed in *Table 5.1*.

Ultrasonographic findings	Number and percentage of cases	Notes
Normal gastrointestinal findings	50 (31 %)	
Thickened gastric wall with normal wall structure	28 (17%)	
Thickened gastric wall with disrupted wall structure	5 (3%)	4 gastritis 1 hyperplasia and retention cyst formation of the gastric glands
Thickened duodenum with normal wall structure	2 (1%)	2 gastroenteritis
Thickened pylorus with normal wall structure	3 (2%)	3 gastroenteritis
General mural thickening of the intestinal wall with normal wall structure	8 (5 %)	8 gastroenteritis
Prominent middle echogenic layer of the intestines with normal overall wall thickness	7 (4 %)	7 gastroenteritis
Decreased peristalsis along the entire GI tract	31 (19 %)	
Increased peristalsis along the entire GI tract	15 (9 %)	
Simultaneous presence of dilated akinetic intestinal loop(s) together with normal intestines	3 (2%)	2 gastroenteritis 1 liver disease
Dilated intestinal loops with increased peristalsis and pendulous movement of the ingesta	1 (1%)	constipation
Duodenal paralysis	1 (1%)	constipation
Fluid filled dilated stomach	26 (16 %)	

Table 5.1 Ultrasonographic findings of the 163 dogs with primary or secondary gastrointestinal inflammatory conditions. Only the most prominent ultrasonographic changes are listed. Some dog had more than one ultrasonographic abnormalities, thus the total number of alterations exceeds the total number of cases.

2. Congenital anomalies

There were 2 dogs with congenital diseases of the gastrointestinal tract (one dog with congenital hypertrophic pyloric stenosis and another one with idiopathic muscular hyperplasia of the small intestines). Ultrasonography revealed thickened wall with normal layered structure of the affected gastrointestinal segments (pylorus or small intestines) in both cases. Thickening of the outer hypoechoic layer of the small intestinal wall was obvious in the dog with muscular hyperplasia *(Fig 5.2).*

Fig.5.1 Ultrasonographic image of a small intestinal loop of a dog in transverse section (black arrow). The intestinal wall is thickened with retained structure. The histological diagnosis revealed lymphocytic-plasmacytic enteritis.

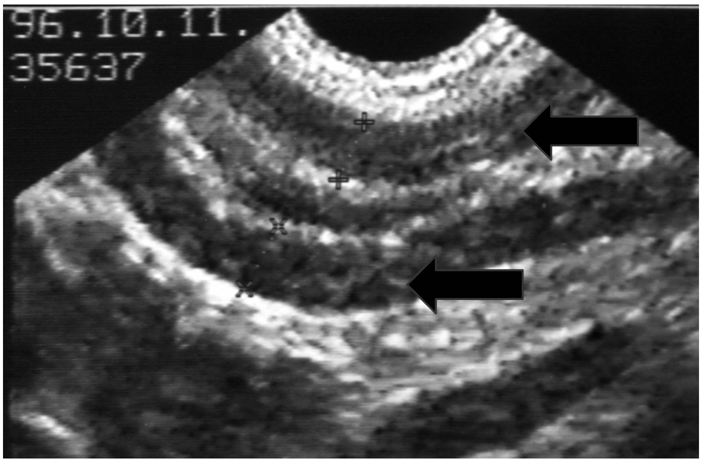

Fig.5.2 The ultrasonographic image of the duodenum of a dog with idiopathic muscular hypertrophy of the entire small intestinal tract. The duodenal wall is thickened and seems hypoechoic, because of the prominent muscular layer. A thin hyperechoic line in the middle of the wall represents the submucosa (black arrows).

3. Gastric foreign bodies

Non-obstructive gastric foreign bodies were diagnosed in two dogs. Echogenic reflex with shadowing and thickened gastric wall was found by the ultrasound in one of them, however no abnormality was observed in the other case.

4. Intestinal obstruction

Mechanical obstruction of the GI tract was diagnosed in 33 dogs including fourteen dogs with intestinal invaginations, ten dogs with ingested foreign bodies, five dogs with intestinal adhesions and one-one cases of intestinal torsion, linear foreign body *(Fig 5.3)*, diaphragmatic hernia and partial obstruction caused by intestinal tumor (liposarcoma).

Invaginated intestines were detected by the ultrasound in 13 of the 14 dogs with intussusceptions (93%), however in two of these dogs no invaginated intestines were found during surgery. The observed sonographic changes are listed in *Table 5.2*.

Ultrasonographic findings	Number and percentage of cases	Notes
Active peristalsis of the dilated intestines and pendulous movement of the luminal content	15 (45 %)	
Invagination	13 (39 %)	There were a total of 14 dogs with the final diagnosis of invagination.
Paralytic intestines and fluid in the abdominal cavity	1 (3 %)	intestinal torsion
Simultaneous observation of intestines with increased and decreased peristalsis	1 (3 %)	
Transonic foreign body in the pylorus	1 (3 %)	Ball
Localized thickening of the intestinal wall with disrupted appearance of the wall	1 (3 %)	intestinal adhesion
Plicated appearance of the intestinal wall	1 (3 %)	linear foreign body
Paralytic intestinal tract	1 (3 %)	
Increased peristalsis and fluid in the abdominal cavity	1 (3 %)	diaphragmatic hernia
Dilated fluid filled stomach	1 (3 %)	
Dilation of some of the intestinal loops	2 (6 %)	

Table 5.2 The observed ultrasonographic findings of the 33 dogs with small intestinal obstruction. Only the most prominent ultrasonographic changes are listed. Some dog had more than one ultrasonographic abnormalities, thus the total number of alterations exceeds the total number of cases. The first five categories of ultrasonographic signs (shaded background) were set as diagnostic criteria for intestinal obstruction in Chapter III.

5. Gastrointestinal neoplasia

Besides the dog with liposarcoma that caused partial obstruction, thus were mentioned among the intestinal obstruction cases, further 8 dogs were diagnosed as having gastrointestinal neoplastic processes. There were six dogs with gastrointestinal lymphoma (it was located to some intestinal loops in five dogs and involved both the stomach and the intestines in one case) and one dog with rectal and another one with gastric polyps. All neoplastic alterations appeared as focal hypoechoic mural masses of the affected GI segments during ultrasonography *(Fig 5.4)*. Enlarged regional lymph nodes were found by the ultrasound in 4 cases, but they were misinterpreted as cystic pancreatic lesions in one dog. Hyperechoic mesenteric fat around the affected intestine was noted in one dog with intestinal lymphoma. In one dog, ultrasonography was normal 2.5 months prior to detecting intestinal lymphoma by a repeated ultrasound examination.

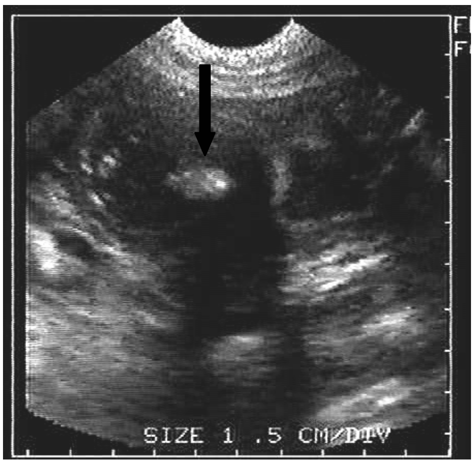

Fig. 5.3 Ultrasonographic image of the intestines of a dog with linear foreign body. The intestines are dilated and have plicated appearance. The foreign body is visible as a hyperechoic reflex with shadowing in the middle of the intestinal lumen (arrow).

Fig. 5.4 Ultrasonographic image of intestinal lymphoma. The intestinal wall has markedly thickened and homogenously hypoechoic without recognizable layers. Gas artifact in the intestinal lumen helps to locate the origin of the mass to the gastrointestinal tract.

6. Gastrointestinal ulceration

There were 9 dogs with the diagnosis of gastrointestinal ulceration. Ultrasonography revealed mural thickening with retained wall structure of the stomach, pylorus, duodenum and the small intestines in 6, 1, 2 and 1 of the cases, respectively. Hyperechoic mesentery was noted in 4 dogs, and hypoechoic lesions in the pancreas region were found in 2 dogs. Two dogs had thickened gastric wall with disrupted structure. Dilated fluid filled stomach was observed in two patients, and in one of them, this was the only observed ultrasonographic alteration.

7. Gastrointestinal perforation

Two dogs were diagnosed with intestinal perforation. Ultrasonography detected paralytic ileus in both cases, while dilated stomach, irritated appearance of the duodenum and free abdominal fluid appeared in one of them.

8. Diseases of the pancreas

There were 43 dogs with acute pancreatitis and 3 dogs had pancreatic tumor (two adenocarcinomas and one dog demonstrated the clinical signs of a possible insulinoma). Ultrasonography revealed hypoechoic pancreas masses and hyperechoic peripancreatic mesentery in 33 (77%) and in 29 (67%) of the 43 dogs with pancreatitis, respectively. The pancreas seemed hyperechoic in one case (2%) and had mixed echogenicity in 3 cases (7%) of pancreatitis. Pancreatitis caused wall thickening with normal structure of the stomach in 7 dogs (16%), that of the pylorus in 2 dogs (5%), that of the duodenum in 10 dogs (23%) and that of the small intestines in 1 case (2%). The normal layered appearance of the thickened gastric wall was lost in one animal with pancreatitis (2%). Other ultrasonographic alterations associated with pancreatitis were dilated stomach in 4 dogs (9%), duodenal paralysis in 3 dogs (7%) and irritated appearance of the duodenum in 2 dogs (5%). No ultrasonographic alterations in the pancreas region were found during three repeated examination of a dog with the clinical signs of insulinoma. Ultrasonography detected hyperechoic peripancreatic mesentery, dilated stomach, thickened gastric wall with normal structure and duodenal paralysis in the two dogs with pancreatic adenocarcinoma.

DISCUSSION

The ultrasonographic changes of different gastrointestinal diseases can be classified in three main categories.

1. Localized or diffuse thickening of the gastrointestinal wall
2. Changes in peristaltic activity
3. Dilatation of the lumen

<u>1. Thickening of the GI wall</u>

Pathological thickening of the GI wall of the dog should be suspected when the wall of the stomach measures more than 6-7 mm and when the intestinal wall measures more than 5 mm (Penninck 1989). Localized thickening of the GI wall together with disruption of the layered appearance may be observed in different neoplastic processes, in severe inflammatory disease, in pancreatitis or in GI ulcers (Penninck 1990, Saunders 1991, Myers and Penninck 1994, Kaser-Hotz et al. 1996, Rivers et al. 1997, Penninck et al. 1997). Thickened gastric wall with irregularly layered appearance (i.e. pseudolayering) is reported to occur in gastric epithelial tumors (Penninck et al. 1998). Observation of regional lymph node enlargement will further increase the likelihood of a neoplastic process according to Kaser-Hotz et al. (1996) and Penninck et al. (1998). Diagnosis can only be achieved by percutaneous or intraoperative biopsy techniques where the former is being performed under ultrasound guidance (Penninck et al. 1993, Crystal et al. 1993). Localized thickening of one layer of the wall can be seen in congenital pyloric stenosis or in chronic hypertrophic pyloric gastropathy (Penninck et al. 1990, Biller et al 1994). Pathological enlargement of the pylorus should be considered in small to medium sized dogs if the length of the pyloric canal exceeds 20 mm, the thickness of the muscular layer exceeds 4 mm, and that of the pyloric wall exceeds 8-9 mm, while the overall diameter of the pylorus exceeds 26 mm (Penninck et al 1990., Biller et al. 1994, Agut et al. 1996). Localized thickening with too many wall layers is observed in case of intestinal invaginations (Flückiger and Arnold 1986, Kantrowitz et al. 1988, Penninck et al. 1990, Watson et al. 1991). The “intestine in intestine” or “target pattern” of intussusceptions is one of the most easily recognizable GI abnormalities. Diffuse thickening with the normal layered appearance generally indicates inflammatory disease or pancreatitis, but diffuse neoplastic disease should be also included in the differential diagnosis (Penninck et al. 1990, Grooters et al. 1994, Spohr et al. 1995, Penninck 1995). Some cases of enteritis may not cause detectable structural changes of the intestinal tract or may result in only luminal distension without wall thickening. Again, diagnosis can only be achieved by histological examination of biopsy specimens.

The findings of the present study were in accordance with previous reports.

Localized thickening of the GI wall with disrupted structure were detected by ultrasonography in 8 dogs with neoplastic disease and in 10 dogs with inflammatory disorders.

Diffuse thickening with retained wall structure in 56 dogs however, were always associated with inflammatory disease in our cases. The ultrasonographic appearances of muscular hypertrophy of the small intestines and gastric glandular hyperplasia described in the present study, have not been published earlier to my knowledge.

Prominent middle echogenic layer of small intestines with normal overall wall thickness were noted in 7 dogs with gastroenteritis. This layer corresponds to the submucosa, which appears on the sonograms normally the same thick as or thinner than the adjacent mucosa. The relative thickening of submucosa observed in these cases may be explained by cellular infiltration of the submucosa and/or by villus atrophy that caused the relative thinning of the mucosal layer. Unfortunately, no histological samples were available from any of these cases, thus the exact explanation of this sonographic sign needs to be sought further.

Invaginations - similarly to earlier published data - were also detected with high accuracy in this study. In two dogs, no invaginated intestines were found during surgery following the ultrasonographic diagnosis of this disorder. Because the ultrasonographic alterations are very specific for intestinal invaginations, the most likely explanation is that the invaginations spontaneously resolved by the time of surgery. Whether or not anesthesia played a role in this process is needed to be investigated further. Detection of blood flow in the wall of invaginated intestinal segments using color Doppler ultrasonography is used to determine the viability of intestines, thus decide further treatment (conservative versus surgery) in children (Lagalla et al., 1994). Using similar approach may help in canine patients to judge whether or not immediate surgery is needed, however the risks of delaying surgery in cases which are not resolving spontaneously or following conservative treatment (enema) should be weighed against those cases where unnecessary operations can be avoided.

2. Changes in peristaltic activity

General increase of GI peristalsis with uniform luminal content movement and mild dilatation of the gastrointestinal lumen was reported in inflammatory disease (Manczur et al. 1998). Observation of localized decrease or lack of peristalsis may be the result of acute pancreatitis, severe localized inflammatory or neoplastic disease (Penninck et al 1990, Myers and Penninck 1994, Rivers et al. 1997, Nyland et al. 1995). Generalized decrease or absence of peristalsis with dilated lumen can be a result of severe inflammatory disease, gastric ulceration, prolonged mechanical obstruction, severe systemic disease or administration of certain drugs (Penninck et al. 1990, Tidwell and Penninck 1992, Myers and Penninck 1994, Penninck et al. 1997, Manczur et al. 1998). Increased peristaltic activity with pendulous movement of the ingesta inside the dilated intestinal loop is a sensitive sign of mechanical obstruction (Manczur et al 1998). Simultaneous observation of different intestinal loops with both increased and decreased peristaltic activity also suggest possible mechanical obstruction (Manczur et al. 1998). These signs have been discussed in Chapter III and IV of this thesis. The findings on peristalsis of the present study were similar to the results of the studies in Chapter III and IV of this thesis.

Normal, generally increased or decreased peristalsis was associated with non-obstructive disorders in 237 of our 239 cases. Paralytic ileus was found in a dog with prolonged mechanical obstruction, and increased peristalsis was noted in a dog with diaphragmatic hernia.

Pendulous movement of the ingesta caused by active peristaltic contractions of the dilated intestine was a sensitive sign of intestinal obstruction. It was associated with mechanical ileus in 15 of the 16 observed cases.

Localized paralysis of the intestines, however is not a sensitive sign of intestinal obstruction, because this finding was associated with non-obstructive diseases in 7 of the 9 observed cases.

3. Dilatation of the lumen

Dilatation of the stomach was observed postprandially, or as a result of a primary or secondary gastric emptying problem. In case of severe dilatation, compartmentalization of the gastric lumen was sometimes observed by me during and outside this study period. It warrants further investigations (e.g. radiography) to exclude the possibility of gastric torsion.

Mild dilatation of the intestinal lumen was seen together with normal peristaltic activity of the gut or in inflammatory disorders.

In contrast, *marked dilatation of the lumen* was observed in paralytic or mechanical ileus cases, as also described earlier by Penninck et al. (1990), and Manczur et al. (1998). Generally, more severe dilatation of the intestines was noted in mechanical than in paralytic ileus, but sonographic measurement of the luminal diameter of the dilated intestines have neither been performed in the present study, nor have been published in veterinary literature.

Large amount of intraluminal gas was present in the intestines of dogs with digestive disorders, or as the effect of intestinal obstruction. Besides accumulation of large amount of intraluminal gas and fluid, intestinal strangulation (volvulus) also produced rapid accumulation of free abdominal fluid as already described in Chapter III of this thesis. In addition, I also often encountered large amount of intraluminal gas in healthy dogs outside of this study.

Linear foreign bodies can appear as echogenic thin intraluminal objects with or without acoustic shadowing. The intestines also look plicated in some cases of linear foreign bodies (Tidwell and Penninck 1992). Other intraluminal foreign bodies may be found sometimes in the stomach or intestinal lumen. Their sonographic picture depends on their shape and acoustic properties (Penninck et al. 1990, Tidwell and Penninck 1992). They often cause shadowing that may be differentiated from that caused by gas, based on the lack of internal echoes inside the shadow ("clean" shadow). In contrast, gas generally produce "dirty" shadowing but the differentiation between the two is not always possible (Tidwell and Penninck 1992, Manczur et al. 1998).

Presence of *intraluminal foreign bodies* were observed in only 3 of the 13 cases of this study. Nevertheless, changes in the peristaltic activity or in the appearance of the GI wall (plication, thickening), or dilation of the lumen were noted in all but one dog with a gastric foreign body.

Because of its functional and anatomical relationship to the GI tract, the findings of the examination of the *pancreas* were also included in this study. Like previous reports, we also found the visualization of the normal canine pancreas to be difficult or even impossible, because of its similar echogenicity to the surrounding tissues (Saunders 1991, Lamb and Simpson 1995, Nyland et al. 1995). Therefore, instead of the visualization of the pancreas itself, a throughout scanning of the pancreas region was performed. A negative sonographic finding probably does not exclude the possibility of a milder disease of the organ, but in the absence of histological examinations, the accurate interpretation of negative ultrasonographic findings is difficult, because neither plain film radiography nor blood chemistry are sensitive and specific enough for a definitive diagnosis. In 37 of the 40 cases when the pancreas was easily recognizable in this study it was associated with acute or subacute pancreatitis. Generally echopoor lesions or masses were found in a more or less hyperechoic peripancreatic mesentery, but increased or mixed echogenicity of the pancreas were also noted. Thickened duodenum or gastric wall, paralytic duodenum, irritated appearance of the adjacent intestines, dilated common bile duct and hepatic lesions often accompanied the structural changes within the pancreas. These changes have been already described in detail by Saunders (1991) and by Nyland et al. (1995). The sonographic alterations were not specific enough to distinguish among the different types of pancreatitis and interestingly, only secondary changes of the surrounding tissues were observed in the two dogs with histologically proven pancreatic tumor. Furthermore, the above mentioned ultrasonographic features were also noticed in other gastrointestinal diseases. Thus, hyperechoic peripancreatic mesentery and/or hypoechoic lesions in the pancreas region were also frequently seen in cases of gastric ulceration.

Based on the results of this retrospective study it can be concluded that ultrasonography is a useful diagnostic imaging method in gastrointestinal abnormalities of the dog.

Changes in the gastrointestinal wall structure, peristalsis, luminal diameter and content and the morphological alterations of the pancreas and adjacent organs were readily detected by this imaging modality.

Localized thickening of the GI wall with disrupted structure was caused by both neoplastic disease and by inflammatory disorders. Diffuse thickening with retained wall structure, however generally was associated with inflammatory disease. Prominent middle echogenic layer of small intestines with normal overall wall thickness was seen in some dogs with gastroenteritis.

Diagnostic criteria set in Chapter III for diagnosing intestinal obstruction were successfully applied on a large number of GI disorders. Localized paralysis of the intestines, although suggested in Chapter IV proved to be an unreliable ultrasonographic sign of intestinal obstruction.

Pancreatitis was most often associated with hyperechoic mesentery and hypoechoic pancreas mass, but similar alterations were encountered in some cases of gastric or duodenal ulceration.

The ultrasonographic appearances of muscular hypertrophy of the small intestines and gastric glandular hyperplasia were described first time in the veterinary medicine.

Even though the observed changes (except invagination and mechanical obstruction) were not specific enough for a definitive diagnosis, ultrasonography was of value to decide further diagnostic processes or treatment of gastrointestinal diseases of the dog.

SUMMARY AND FINAL CONCLUSIONS

THE ROLE OF ULTRASONOGRAPHY IN THE DIAGNOSTIC PROCESS OF CANINE GASTROINTESTINAL DISEASES

Acute or chronic gastrointestinal (GI) diseases of the dog often call for a diagnostic imaging method during the diagnostic workup. Nowadays, this would include plain film or contrast radiography, fluoroscopy, scintigraphy, computed X-ray tomography (CT), endoscopy and ultrasonography. Radiography (both plain film and contrast) has a well-established place in the diagnostic process of these disorders. Although widely used, ionizing radiation, low sensitivity and time consuming nature of radiographic contrast techniques are well known disadvantages of these methods (Wolvekamp 1989, Weichselbaum et al. 1994). The primary technique of both human and veterinarian professionals involved in gastroenterology is endoscopy, which provides the possibility of observing the GI tract from the lumen. By built-in histology-sampling devices the exact histological diagnosis is also available by this method. The main disadvantages are the need for anesthesia, and the fact that the largest part of the GI tract is not accessible for endoscopy. In addition, this technique does not provide any information about the involvement of other organs, like lymph nodes, surrounding tissues, pancreas, liver or the kidneys. The combination of endoscopy and ultrasonography in endosonography only partly overcomes these disadvantages. In addition it is not yet available for routine application. The use of fluoroscopy, scintigraphy or CT is limited to university clinics and are not expected to be soon part of the diagnostic workup of an average veterinary practice. In contrast, ultrasonography is getting more and more available for everyday use, and has become the number one imaging method of several parenchymal diseases.

The aim of this Ph.D. research was to investigate the use of ultrasonography in canine gastrointestinal diseases. This thesis consists of five studies answering various questions raised by clinical diagnostic application of the technique.

In the first chapter, in vitro and in vivo ultrasonographic appearances of the GI tract of the dog and those of isolated GI segments were compared before and after formaldehyde fixation. It was found that the in vivo and in vitro ultrasonographic structure of the GI tract is similar and not affected by formaldehyde fixation. As a result, it can be concluded that detailed ultrasonographic waterbath study of surgically or pathologically dissected GI segments is possible after formaldehyde fixation without hindering later histological examination. Ultrasonographic measurements of the GI wall thickness were also performed during this study. Considerable differences between in vivo and in vitro GI wall thickness measurements were stated, which was explained by post mortal changes of the segments, the waterbath media and the transducer position. This latter is of special importance when measuring GI wall thickness in living animals. To minimize erroneous ultrasonographic measurement of the gastrointestinal tract, the transducer should be always kept perpendicular to a gastrointestinal segment and measurement should be done when the largest luminal diameter, hence the thinnest wall thickness is observed in saggital section. On the contrary, measurements in transverse view should be done when the smallest and most circular luminal area is observed.

In the second chapter, three modified radiographic contrast techniques were tried using various fluids as ultrasonographic contrast media. The effect of fluid administration to the stomach for a small bowel follow through study, of the enteroclysis technique, and of the reflux examination was assessed on the quality of ultrasonographic images of the gastrointestinal tract in healthy dogs. The reflux examination proved to be the most promising sonographic contrast technique for the visualization of the small and large intestines. Disadvantages of the reflux examination are that the animals have to be sedated and prepared by previous enemas for an optimal examination, which limits the clinical use of the technique. Because this technique causes paralysis of the intestines, the peristaltic activity should be assessed prior to this examination. No considerable difference was found among the different fluids used as contrast media during this study. It was not possible to systematically follow the whole intestinal tract from pylorus to rectum or vice versa, even when it was completely filled with fluid. Thus, a systematic scanning of the entire abdomen is required during ultrasonography of the gastrointestinal tract. If gas containing gastrointestinal segments are encountered, their negative effect can be avoided by positional changes and compression, similarly to non-contrast sonographic techniques. Fluid administration through a gastric tube helped to visualize the stomach and duodenum but fails to produce marked improvement of the ultrasonographic quality in other parts of the GI tract. Gas removal and application of smooth muscle relaxant drugs may improve the effectiveness of this technique.

The third chapter contains a study that was aimed to establish ultrasonographic criteria and assess its use in the diagnosis of canine small bowel obstruction. Ultrasonography was performed on 44 dogs to decide whether small bowel obstruction had been present. Sonographic criteria for small bowel obstruction were 1. the presence of pendulous movement of the ingesta inside the dilated bowel, or 2. observation of invaginated intestines or an ingested intraluminal foreign body, or 3. observation of non-uniform peristaltic activity of the dilated intestines, or 4. observation of akinetic intestinal loops together with abdominal fluid accumulation. By using these criteria, intestinal obstruction was correctly diagnosed by ultrasonography in 11 of the 13 dogs with mechanical ileus, and obstruction was correctly excluded in 29 of the 31 non-obstructive cases. Thus, the above mentioned sonographic criteria had 85 % sensitivity and positive predictive value, and 94 % specificity and negative predictive value. Based on these findings, the author suggests that ultrasonography is a valuable tool to diagnose small intestinal obstruction in the dog.

In the fourth chapter, the author further challenged the use of the previously described sonographic criteria for small bowel obstruction by comparing its diagnostic value with that of plain film radiography. Results of 46 ultrasonographic examinations and 45 survey radiographs of 45 dogs with the clinical signs of ileus were compared with the final diagnosis in a two year period. 11 dogs had intestinal obstruction and 34 animals suffered from other diseases that caused no obstruction. Intestinal obstruction was correctly diagnosed by ultrasonography in 8 of the 11 dogs with mechanical ileus, while the possibility of intestinal obstruction was correctly excluded in 32 of the 34 dogs without intestinal obstruction. Intestinal obstruction was correctly diagnosed by radiography in 10 of the 11 cases, while mechanical ileus was correctly excluded in 25 of the 34 cases. The sensitivity, specificity, positive and negative predictive values of ultrasonography in the diagnosis of small bowel obstruction were 73 %, 91 %, 73 % and 91 % respectively, whereas those for plain film radiography were 91 %, 74 %, 53 % and 96 %, respectively. When the largest small intestinal diameter per fifth lumbar vertebral body height ratio of 1.6 was used as threshold level for diagnosing small intestinal obstruction on the radiographs, the diagnostic value of radiography was increased. It is concluded that ultrasonography is a less sensitive and more specific technique than survey radiography in diagnosing small intestinal obstruction of the dog. The combination of the two imaging methods highly improved diagnostic capability and resulted in very accurate decisions about the need of surgical interventions of dogs with signs of ileus. The diagnostic value of radiography was increased by using more objective criteria. A similar approach in ultrasonography using bowel measurements and Doppler signs may have similar effect on the diagnostic value of ultrasonography.

Finally, in the fifth chapter, the role of ultrasonography in canine GI disorders was investigated on a large number of clinical cases. The findings of ultrasonography of the gastrointestinal tract of 265 dogs were analyzed. The ultrasonographic changes associated with various inflammatory, neoplastic conditions and mechanical obstruction of the gastrointestinal system were discussed. In addition, sonographic alterations of the pancreas and the tissues adjacent to the GI tract were also included in the study. The ultrasonographic alterations of the GI tract were classified in three main categories: thickening of the gastrointestinal wall, changes in peristalsis and dilation of the lumen. Changes in the gastrointestinal wall structure, peristalsis, luminal diameter and content and the morphological alterations of the pancreas and adjacent organs were readily detected by this imaging modality. Localized thickening of the GI wall with disrupted structure was caused by both neoplastic disease and by inflammatory disorders. Diffuse thickening with retained wall structure, however generally was associated with inflammatory disease. Prominent middle echogenic layer of small intestines with normal overall wall thickness was seen in some dogs with gastroenteritis. Diagnostic criteria set in Chapter III for diagnosing intestinal obstruction were successfully applied on a large number of GI disorders. Localized paralysis of the intestines, although suggested in Chapter IV proved to be an unreliable ultrasonographic sign of intestinal obstruction. Pancreatitis was most often associated with hyperechoic mesentery and hypoechoic pancreas mass, but similar alterations were encountered in some cases of gastric or duodenal ulceration. The ultrasonographic appearances of muscular hypertrophy of the small intestines and gastric glandular hyperplasia were described first time in the veterinary medicine. Even though the observed changes (except invagination and mechanical obstruction) were not specific enough for a definitive diagnosis, ultrasonography was of value to decide further diagnostic processes or treatment of gastrointestinal diseases of the dog.

Based on the result of this Ph.D. research and on the published observations of other authors it can be stated that ultrasonography is a useful diagnostic imaging technique in canine GI disorders. Changes of the canine GI wall morphology, luminal diameter, luminal content, peristaltic activity as well as structural changes of the surrounding tissues and organs can all be detected by ultrasonography. It provides important but generally nonspecific information, which may still be essential for the decision of further examination or treatment of the animal. The author of this thesis suggest the use of GI ultrasonography as a complementary diagnostic technique to plain film radiography. Plain film radiographs provide an overview of the abdomen and detect mass lesions or marked GI luminal dilation. Ultrasonography can further define these lesions if the findings of radiography equivocal or can provide further information about the GI wall structure and peristalsis that are not recognizable by radiography. It is worth to mention that ultrasonography is a highly operator dependent technique. Performed by an expert, GI ultrasonography is capable to almost completely replace contrast radiography. The author would like to stress here again the nonspecific nature of different ultrasonographic alterations of the GI tract, that with a few exceptions, e.g. invagination or intestinal obstruction, warrant further diagnostic processes (e.g. biopsy) to achieve the final diagnosis. The findings of ultrasonography should be always interpreted together with the history, the physical examination and the results of other additional tests in order to avoid the biased overestimation of this useful technique.

ÖSSZEFOGLALÁS ÉS VÉGSŐ KÖVETKEZTETÉSEK

AZ ULTRAHANGVIZSGÁLAT SZEREPE KUTYÁK GYOMOR-BÉL BETEGSÉGEINEK KÓRJELZÉSÉBEN

A kutyák heveny és idült gyomor-bél betegségeinek vizsgálata során gyakran felmerül valamely diagnosztikai képalkotó eljárás használatának az igénye. Manapság ez natív és kontrasztos röntgen eljárásokat, fluoroszkópiás, nukleáris szcintigráfiás, komputertomográfiás, endoszkópos vagy ultrahangvizsgálatokat jelenthet. A natív és kontrasztos röntgen eljárásoknak már régóta jól megalapozott szerepe van e kórképek diagnosztizálásában. E két módszer széles körben elterjedt, hátrányuk azonban az ionizáló sugárzás mellett, a kontrasztos eljárások időigényessége és alacsony specifitása. Az állatorvosi diagnosztikában is terjedőben van a gasztroenterológiai endoszkópia, amely az elváltozások lumen felőli megtekintését és biopszia vétele révén a pontos szövettani diagnózis lehetőségét nyújtja. Hátránya, hogy az egyes betegségek nem minden esetben okoznak a nyálkahártyán is észlelhető elváltozást, a környező szövetek állapotáról nem nyújt semmiféle információt, továbbá a jejunum teljes hossza gyakorlatilag nem elérhető az endoszkóp számára. Az ultrahang és az endoszkóp kombinációjaként létrehozott endoszonográf csak részben tudja ezeket a hátrányokat leküzdeni. Ezen kívül használata csupán az állatorvosi egyetemekre és igen jól felszerelt nagyobb klinikákra korlátozódik. A fluoroszkópia, a nukleáris szcintigráfia, illetve a komputertomográfia egyelőre még szintén nem fog szerepet kapni a hétköznapi állatorvosi praxisban. Már napjainkban is elterjedt és a kisebb praxisok számára is mind elérhetőbbé válik azonban az ultrahang használata. Így jogosan merül fel az igény e vizsgáló eljárásnak, a kutyák gasztroenterológiai kórképeinek felderítésében betölthető szerepének meghatározására.

Kutatásom célja az volt, hogy megvizsgáljam az ultrahangvizsgálat lehetséges szerepét kutyák gyomor-bél elváltozásainak diagnosztizálásában. Munkám öt részre tagolódott.

Az első fejezetben kutyák gyomor-bél csatornájának in vivo és in vitro ultrahang szerkezetét hasonlítottam össze, továbbá izolált bélszakaszok in vitro vizsgálata során megvizsgáltam a formaldehidnek a bélfal ultrahangszerkezetére gyakorolt hatását. Vizsgálataim során arra az eredményre jutottam, hogy a bélfal in vivo és in vitro ultrahang szerkezete hasonló, és ezt a szerkezetet a formaldehides rögzítés sem változtatja meg. Ez alapján elmondható, hogy sebészileg vagy kórbonctanilag eltávolított bélszakaszok részletes ultrahangvizsgálata vízfürdőben lehetséges formaldehides rögzítés után, annak a veszélye nélkül, hogy e vizsgálatok a későbbi szövettani vizsgálatok elvégzését megakadályoznák. E kísérletek során az ultrahang segítségével megmértem a bélfal vastagságát az élő állatokban, illetve a halál után eltávolított bélszakaszok falvastagságát formaldehides rögzítés előtt és után is. Az élő kutyákban történt mérések sokszor jelentősen különböztek az izolált bélszakaszokon felvett méretektől. Ennek okát, a halál után bekövetkező változásokra, a vízfürdő közegére és a vizsgálófej bélszakaszhoz viszonyított helyzetére vezettem vissza. Ez utóbbi az élő állatokon történő mérések pontosságát is befolyásolhatja. A helyes méréshez a vizsgálófejet mindig merőlegesen kell tartani az adott bélszakaszra. A méreteket (pl. falvastagság) akkor kell felvenni amikor a legnagyobb lumenátmérő, azaz a legvékonyabb bélfal látható a hosszmetszeti képen. Ezzel szemben, amikor keresztmetszetben ábrázoljuk a beleket, a méréseket a legkisebb és egyben legkerekebb béllumen ábrázolódása mellett tudjuk a legpontosabban elvégezni.

Az értekezés második fejezetében három, a röntgenvizsgálatok során alkalmazott kontraszt technika (gyomorfeltöltés, enteroclysis és reflux vizsgálat) ultrahangos adaptálását próbáltam ki egészséges kutyákon. E kísérletek során megvizsgáltam a különféle folyadékoknak, mint ultrahang kontrasztanyagoknak, gyomor, duodenum és rectalis szondán át történő bejuttatásának hatását a gyomor-bél csatorna ultrahang képének minőségére. A kísérletek során a rectalis szondán keresztül történő feltöltés, az ún. reflux vizsgálat, bizonyult a legígéretesebb eljárásnak. A vizsgálat gyakorlati értékét azonban rontja, hogy az állatokat előzetes beöntésekkel és szedálással kell előkészíteni a vizsgálathoz. Mivel az eljárás átmeneti bélbénulást okoz, a perisztaltikát a beöntést megelőzően kell megítélni. Az általam alkalmazott folyadékok között nem találtam az ultrahangkép minőségét befolyásoló lényeges különbséget. A vizsgálataim során megállapítottam, hogy a gyomor-bél csatorna a pylorustól a rectumig, illetve viszont történő ultrahang követése még teljesen feltöltött állapotban sem lehetséges. Ezért e szervrendszer ultrahangvizsgálatakor elengedhetetlen a has alapos, több vizsgálati síkból elvégzett átpásztázása. Vizsgálataim alapján az is elmondható, hogy a gyomorszondán keresztüli folyadékbejuttatás csak a gyomor és duodenum ultrahang elbírálását könnyíti meg, a bélcsatorna további szakaszára azonban csekély hatással bír. Ez utóbbi eljárás diagnosztikai értékét tovább növelheti a gyomorban található gáz előzetes eltávolítása és simaizom relaxáns gyógyszerek egyidejű alkalmazása.

A harmadik fejezetben, kutyák bélelzáródása során észlelhető ultrahang-diagnosztikai kritériumokat állítottam fel, és ezek értékelését végeztem el. Ennek érdekében 44 olyan beteg kutyát vizsgáltam az ultrahang segítségével, ahol a bélelzáródás gyanúja a fizikális vizsgálat alapján felmerült. Bélelzáródásra utaló ultrahangjelnek tekintettem ha: 1) a béltartalom ingamozgását láttam a kitágult bélszakasz(ok)ban, vagy 2) bélbetüremkedést, illetve ultrahanggal ábrázolható idegen tárgy jelenlétét észleltem, vagy 3) a bélperisztaltika eltérő jellegét figyeltem meg a bélcsatornán, vagy 4) paralitikus bélszakasz(oka)t és hasűri folyadék-felhalmozódást találtam az ultrahangvizsgálat során. A fenti diagnosztikai jelek használatával a 13 bélelzáródásban szenvedő állat közül 11-ben tudtam az elzáródást ultrahanggal diagnosztizálni, illetve a 31 egyéb betegségben szenvedő kutya közül 29 esetben kizárni a bélelzáródás lehetőségét. Az általam felállított ultrahang kritériumok így 85%-os szenzitivitással és pozitív predikciós értékkel, valamint 94%-os specifitással és negatív predikciós értékkel bírnak. Mindezek alapján megállapítottam és igazoltam, hogy a kutyák bélelzáródásának diagnosztizálásában az ultrahangvizsgálat jól használható, értékes eljárás.

A negyedik fejezetben, a harmadik vizsgálat során felállapított ultrahang-diagnosztikai jelek értékelését folytattam azáltal, hogy azokat a hagyományos röntgenvizsgálat érzékenységével vetettem össze. Ennek során 45 olyan beteg kutya azonos számú röntgen és 46 ultrahangvizsgálatának eredményét hasonlítottam össze a végső diagnózissal, amelyeknél a kórelőzmény és a fizikális lelet felvetette az ileus gyanúját. Ultrahangvizsgálattal a 11 bélelzáródásos állat közül 8-ban, míg a 34 egyéb betegségben szenvedő kutya közül 32-ben tudtam a bélelzáródást megállapítani, illetve kizárni. A natív röntgenfelvételek alapján 10, illetve 25 esetben lehetett ugyanezt megtenni. Az ultrahangvizsgálat érzékenysége 73%-os, specifitása 91%-os, míg pozitív és negatív predikciós értéke 73 és 91%-os volt. Ugyanezek a jellemzők 91, 74, 53 és 96%-os értéket mutattak a röntgenvizsgálatok alapján. Amikor a röntgenfelvételek kiértékelésében a legnagyobb vékonybélátmérő és az ötödik ágyékcsigolya testének hányadosát 1.6-os határértékkel is figyelembe vettük, a röntgenvizsgálat diagnosztikai értéke javult. A fentiek alapján elmondható, hogy kutyák bélelzáródásának diagnosztizálásában az ultrahangvizsgálat a natív röntgenvizsgálatnál kevésbé érzékeny, azonban specifikusabb vizsgálóeljárás. A röntgenvizsgálat diagnosztikai értékét az objektív kritériumok alkalmazása javította, hasonló módon (a belek átmérőjének mérésével) az ultrahangvizsgálat is feltehetően tovább pontosítható. A két eljárás együttes használata alapján a sebészi beavatkozás szükségességét igen nagy pontossággal lehet meghatározni.

Munkám befejező részében, *az ötödik fejezetben*, a kutyák gyomor-bél ultrahangvizsgálatának tapasztalatait 265 klinikai beteg vizsgálata alapján írtam le, alkalmazva a harmadik és negyedik fejezetekben kapott eredményeket is. E vizsgálat során a különféle gyulladásos, bélelzáródásos és daganatos gasztroenterológiai betegségekben szenvedő kutyák ultrahangvizsgálata során tapasztalható gyomor-bél elváltozások, továbbá a hasnyálmirigy és a környező szövetek elváltozásait elemeztem. A gyomor-bél csatorna rendellenességeit három fő csoportba osztottam, mégpedig a bélfal megvastagodása, a lumen kitágulása és a bélperisztaltika megváltozása alapján. A gyomor és bélfal helyi megvastagodása, továbbá a falszerkezet elmosódottá válása egyaránt jellemző volt a daganatos és a gyulladásos betegségekre. Ezzel szemben a bélfal diffúz megvastagodását megőrzött falszerkezet mellett általában gyulladásos betegségek esetén lehetett észlelni. A bélfal középső, echódús rétegének relatív megvastagodását több bélgyulladásban szenvedő kutya esetében is tapasztaltam. A harmadik fejezetben megállapított kritériumokat sikeresen tudtam nagy létszámú beteganyagon használni. A negyedik fejezetben ismertetett kutatásom alapján felvetődött, hogy a helyi bélbénulás észlelése is felhasználható a kutyák bélelzáródásának ultrahang-diagnosztikájában. A mostani eredmények alapján azonban ez a jel nem bizonyult kellőképpen megbízhatónak. A heveny hasnyálmirigy gyulladás többnyire a hasnyálmirigy tájékának echóintenzitás csökkenésével és a környező szövetek echóintenzitásának növekedésével járt, bár hasonló ultrahangjeleket egyes gyomor és nyombélfekélyben szenvedő ebek esetén is megfigyeltem. E vizsgálatok során elsőként írtam le két elváltozás (a vékonybél idiopátiás simaizom- és a gyomor glandularis mirigyeinek hyperplasiájának) ultrahangjeleit. Az észlelt ultrahangeltérések, az invaginatio és a bélelzáródás megállapításának kivételével, nem voltak alkalmasak arra, hogy általuk pontos kórjelzéshez lehessen jutni, mégis, az ultrahangvizsgálat hasznos eszköznek bizonyult a további diagnosztikai és terápiás eljárások megválasztásában.

Ph.D.-kutatásom eredményei és a szakirodalom alapján úgy tűnik, hogy az ultrahangvizsgálat a kutyák heveny és idült gyomor- és bélbetegségek esetén is az egyik első kiegészítő műszeres vizsgálat szerepét töltheti be. Használatával megítélhető a gyomor-bél csatorna falának szerkezete, a perisztaltikus mozgások, a béllumen tágassága és tartalma, valamint a környező szövetek és parenchymalis szervek állapota. Ezáltal olyan értékes, bár általában nem specifikus információkhoz jut a klinikus, ami a beteg további vizsgálatához, kezeléséhez nélkülözhetetlen lehet. Alkalmazása jól kiegészíti a natív röntgenvizsgálatét, amely átnézeti képet nyújt a hasüregről, továbbá segítségével kimutatható a bélcsatorna kitágulása és a hasüregben lévő esetleges gócos elváltozások. Az ultrahang használatával ezeknek az elváltozásoknak további részletei vagy akár a natív röntgenvizsgálattal nem ábrázolható olyan rendellenességek is

láthatóvá tehetőek mint pl. a bélperisztaltika, illetve a bélfal szerkezetének a megváltozása. Fontos megemlíteni, hogy az ultrahangvizsgálat érzékenységét a vizsgáló személy jelentősen befolyásolja. A módszer szakképzett vizsgáló kezében gyakorlatilag szinte teljesen kiválthatja a kontrasztos röntgeneljárások használatát. Ismét hangsúlyozni szeretném, hogy az ultrahanggal észlelhető elváltozások - az invaginatio és a bélelzáródás kivételével - nem specifikusak és a végső diagnózis meghatározásához további vizsgálatok (pl. biopszia) elvégzése szükséges. Az ultrahangvizsgálat eredményét a kórelőzmény, a fizikális és kiegészítő vizsgálatok leleteivel együttesen kell kiértékelni ahhoz, hogy e hasznos módszer esetleges aránytalan túlbecsüléséből adódó hibákat elkerülhessük.

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