Comparison of contrast media for visualization of the colon of healthy dogs during computed tomography and ultrasonography

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OBJECTIVE
To evaluate contrast agents for their ability to improve visualization of the colon wall and lumen during CT and ultrasonography.

ANIMALS
10 healthy adult Beagles.

PROCEDURES
Food was withheld from dogs for 36 hours, after which dogs consumed 250 mL of polyethylene glycol solution. Dogs were then anesthetized, a contrast agent (tap water, diluted barium, or air; order randomly assigned) was administered rectally, iodine contrast medium (880 mg of I/kg) was administered IV, and CT and ultrasonography of the colon were performed. After a 1-week washout period, this process was repeated with a different contrast agent until all agents had been evaluated. Two investigators reviewed the CT and ultrasonographic images for colon wall thickness, conspicuity, artifacts, wall layering, and degree of lumen dilation at 4 sites.

RESULTS
Thickness of the colon wall was greatest in CT and ultrasonographic images with water used as contrast agent, followed by barium and then air. The CT images obtained after water administration had a smooth appearance that outlined the colonic mucosa and had the highest score of the 3 contrast agents for wall conspicuity. Although no substantial artifacts related to any of the contrast agents were identified on CT images, barium- and gas-induced shadowing and reverberation artifacts hindered wall evaluation during ultrasonography. For ultrasonography, the degree of conspicuity was highest with barium in the near-field wall and with water in the far-field wall. In contrast to CT, ultrasonography could be used to distinguish wall layering, and the mucosal and muscular layers were distinct with all contrast agents.

CONCLUSIONS AND CLINICAL RELEVANCE
Use of water as a contrast agent for both CT and ultrasonography of the colon in dogs compensated for each imaging modality's disadvantages and could be beneficial in the diagnosis of colon disease. (*Am J Vet Res* 2016;77:1220–1226)

The large intestine of dogs can be affected by various conditions, including inflammation, tumors, motility disorders, strictures, herniation, foreign bodies, torsion, and intussusception.[1] Colitis is the most commonly diagnosed disorder, and it is responsible for intestinal disease in up to 45% of affected dogs. Malignancies such as adenocarcinomas, lymphomas, and gastrointestinal stromal tumors can develop in the large intestine and are more common than tumors in the stomach or small intestine.[2] In most diseases involving the large intestine, thickness and layering of the wall, luminal contents, and lumen (intact without narrowing or obstruction) as well as diffuse or focal changes of the mucosal, muscular, and serosal layers should be investigated to determine the extent of pathological changes and formulate a treatment plan.

Colonoscopy is the most sensitive diagnostic tool for large intestinal disease in human medicine; however, the success of colonoscopy is highly dependent on the operator's skill and experience.[3] Adverse effects related to colonoscopy (eg, colonic perforation, laceration of blood vessels, and translocation of microflora through the mucosa) have been reported.[4] Moreover, colonoscopy has limitations when it comes to estimating function of the colon, measuring luminal diameter, or investigating diseases associated with the submucosal, muscular, and serosal layers of the colon.[5]

Most diseases of the large intestine are associated with structural changes involving the lumen or intestinal wall. Diagnostic imaging can detect and clarify the extent of lesions on the basis of structural chang-

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es.[6] Some conditions (eg, foreign bodies, intestinal torsion, intussusception, or extraluminal mass effects) can be detected with survey radiography when the lesions accompany typical radiographic findings. Use of positive or negative contrast agents can improve the sensitivity of radiography, but the inherent limitation of radiography, namely superimposition of the large intestine by the surrounding organs, interferes with detailed examination of intestinal lesions, even when contrast agents are used.[6]

Ultrasonography, which allows cross-sectional imaging, can be used to assess intestinal lesions without overlap of adjacent structures being an issue. Ultrasonography is extremely useful for examination of wall layers and can be used to investigate any loss of wall layering, which is a good predictive factor in tumor management.[7] In particular, this modality can be used to define the origin and extent of a mass originating from the gastrointestinal tract. Ultrasonography is also useful for diagnosing intussusceptions or identifying thickening of the intestinal wall. Thickening of the intestinal wall can occur with inflammation, infection, ischemia, edema, hemorrhage, and neoplasia. In particular, neoplasia can cause diffuse, symmetric wall thickening in the colon.[8] Ultrasonography is typically used as an adjunct to radiography because it has lower spatial resolution than radiography, and image quality is limited because of critical artifacts caused by gas and fecal material within the intestine.[6]

Hydrograms, which are obtained by use of fluid-filling techniques, are used to overcome problems associated with gas-related artifacts and to provide a good acoustic window for examination of the gastrointestinal tract.[9] The stomach is dilated with fluid in hydrogram ultrasonography, and the collapsed stomach in fasting human patients can be easily distinguished from any tumor. Hydrograms can be helpful to identify wall layers and the lumen of the intestine and to clarify the extent of a tumor originating from the gastrointestinal tract. Therefore, hydrogram ultrasonography is considered to be complementary to endoscopy for use in the diagnosis of submucosal tumors and an alternative to other expensive imaging techniques such as endoscopic ultrasonography.[9] In addition, a modified double-contrast barium enema with carboxymethylcellulose administered into the rectum has been shown to be useful for immediate radiographic and ultrasonographic evaluation of the morphology and mucosal layers of the colon in dogs.[10]

Computed tomography can eliminate the superimposition of organs adjacent to the large intestine and provide a 3-D representation of the intestinal tract through postprocessing reformatting. However, fecal material in the colon can mask underlying lesions, and emptying the colon leads to collapse of the colonic lumen and contraction of the muscular wall, even on CT images. Computed tomographic examinations with orally administered contrast agents (eg, iodine, diluted barium, neutral contrast agents, room air, or CO_2) have been used to overcome these shortcomings, but it is difficult to optimize visualization of the distal part of the large intestine.[11,12]

Radiographic colonography, ultrasonography, and CT after administration of an enema are primarily used for diagnostic imaging of the large intestine, and each method has its strengths and weaknesses. The purpose of the study reported here was to identify the best contrast agent (room air, diluted barium, or tap water) for diagnostic imaging of the colon and to compare the relative benefits of ultrasonography and CT for this purpose. The hypothesis was that hydrogram ultrasonography could be easily applied to the large intestine and used to clearly indicate the lumen and wall layers of the colon through uniform filling of the colon with contrast agents. In addition, hydrogram ultrasonography would be suitable for examining the wall layers of the colon, and hydrogram CT would be suitable for examining the colonic lumen. The effects of contrast agents on image quality and intestinal filling were investigated in clinically normal dogs to determine the protocol that would optimally provide luminal distention and intestine layering and a minimal amount of artifacts during ultrasonography and CT of the colon.

Materials and Methods

Animals

Ten healthy adult Beagles (9 males and 1 female) were used in the study. Body weight of the dogs ranged from 8 to 14 kg. All dogs were deemed healthy on the basis of results of a physical examination, CBC, serum biochemical analysis, electrolyte analysis, and fecal examination. The study protocol was approved by the Institutional Animal Care and Use Committee of Chonnam National University (CNU IACUC-YB-R-2015-25).

Experiment 1

Three contrast agents (room air, tap water, and diluted barium [1.5% {wt/vol}]) were evaluated separately for use in CT examination of the colon, with a 1-week washout period provided between evaluations. Order of administration was randomly assigned. For each evaluation, food was withheld from all dogs for 36 hours, and dogs were then allowed to consume 250 mL of polyethylene glycol solution,[a] which was placed in a bowl.[6] Anesthesia was induced by IM administration of a combination of zolazepam-tiletamine[b] (1.5 mg/kg) and medetomidine[c] (0.03 mg/kg). Each dog was positioned in ventral recumbency, with the cranial aspect of the body kept lower than the caudal aspect of the body. A 20F balloon-tipped Foley catheter was passed into the rectum. Contrast agent was administered rectally at a dose of 20 mL/kg; injections were stopped once positive pressure was encountered. In addition, iodine contrast medium[d] (880 mg of I/kg) was injected IV.

Computed tomography was performed by use of a 16-channel multidetector CT[e] with the following

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settings: 130 kVp; 100 mA; slice thickness, 1 mm; and pitch, 0.8. The CT scan was repeated 2 minutes after completion of the initial CT scan. All CT images were transmitted to a picture archiving and communication system and evaluated at a workstation by 2 investigators (BGC and SHM), who used a window width of 400 Hounsfield units and window level of 40 Hounsfield units. Four sites of the large intestine were evaluated: the distal portion of the descending colon at the neck of the urinary bladder, midportion of the descending colon at the level of the caudal pole of the left kidney, midportion of the transverse colon caudal to the body of the stomach, and midportion of the ascending colon at the level of the caudal pole of the right kidney. Wall thickness was measured on transverse CT images at each site by each investigator separately. Conspicuity of the layers of the dorsal and ventral portions of colon wall and lumen dilation on CT images were subjectively scored by use of a 3-point scale (1 = poor, 2 = adequate, and 3 = optimal). Beam-hardening artifacts were also subjectively scored by use of a 3-point scale[13] (1 = barely perceptible, 2 = noticeable, and 3 = interpretation limit).

Experiment 2

Immediately after CT examination was completed, ultrasonography of the colon was conducted to evaluate the contrast agents. The ultrasonography was performed with each dog in dorsal or right lateral recumbency as necessary to obtain the optimal ultrasonographic images. Ultrasonography was performed with a 10-MHz linear transducer.[f] The same 4 sites of the large intestine as examined via CT were identified, and each site was scanned and evaluated separately by the same 2 investigators who performed the CT examinations. Wall thickness was measured from the hypoechoic mucosa to the hyperechoic serosa in transverse images at each site by each investigator separately. Wall conspicuity was subjectively scored for the near-field and far-field portions of the colon wall by use of a 3-point scale (1 = poor, 2 = adequate, and 3 = optimal). Discrimination among the 5 wall layers was also subjectively scored by use of a 3-point scale[13] (1 = poor, 2 = adequate, and 3 = optimal).

Statistical analysis

Statistical analysis was performed with statistical software.[g] Data for wall thickness and subjective scores are reported as mean ± SD values. Three-way ANOVA was performed to evaluate differences in wall thickness among the contrast agents and sites and between the investigators. Association between estimated wall thickness and body weight was evaluated by use of the Student *t* test. Differences in wall thickness, conspicuity, and lumen dilation between CT and ultrasonography were compared by use of the paired *t* test. Subjective values (eg, conspicuity, wall layering, artifacts, and lumen dilation for each contrast medium) were compared by 1-way ANOVA. Thickness of the colon wall estimated on transverse and longitudinal ultrasonograms was compared by use of the paired *t* test. Differences were considered significant at $P < 0.05$.

Results

None of the dogs had signs of clinical problems related to rectal administration of contrast agents or procedures involved in the CT and ultrasonographic examinations. No evidence of vomiting, hematochezia, or diarrhea was detected. Results of initial CT examinations (ie, before rectal administration of contrast agent) were not analyzed because most of the colon was collapsed in those images.

Mean ± SD thickness of the colon wall measured by use of CT and ultrasonography was summarized **(Tables 1 and 2)**. Overall mean thickness measured at 4 sites for all 3 contrast agents was within previously reported reference limits.[2] Mean ± SD thickness of the colon wall measured on the precontrast CT images (2.13 ± 1.09 mm) was greater than that measured on postcontrast CT images (1.18 ± 0.44 mm). For each contrast agent, thickness of the colon wall did not differ significantly among the 4 sites, except for the dorsal portion of the colon wall on CT images, which was significantly thicker in the distal portion of the descending colon and significantly thinner in the midportion of the colon.

Thickness of the colon wall differed significantly, depending on the contrast agent used (Tables 1 and 2). The colon wall was thickest on CT and ultrasono-

Table 1—Mean ± SD thickness (mm) of 2 portions of the colon wall of 10 healthy adult Beagles measured by use of CT after rectal administration of 3 contrast agents.

Portion	Tap water (n = 80)*	Diluted barium (n = 80)*	Room air (n = 80)*
Ventral	1.41 ± 0.42[a]	1.21 ± 0.39[b]	1.08 ± 0.37[c]
Dorsal	1.27 ± 0.40[a]	1.26 ± 0.56[b]	0.87 ± 0.28[c]

*The n represents results for 10 dogs, 4 sites/dog (the distal portion of the descending colon at the neck of the urinary bladder, midportion of the descending colon at the level of the caudal pole of the left kidney, midportion of the transverse colon caudal to the body of the stomach, and midportion of the ascending colon at the level of the caudal pole of the right kidney), and 2 investigators.

[a–c]Within a row, values with different superscript letters differ significantly ($P < 0.001$).

Food was withheld from dogs for 36 hours, after which dogs consumed 250 mL of polyethylene glycol solution. Dogs were then anesthetized, a contrast agent (tap water, diluted barium, or air) was administered rectally, iodine contrast medium (880 mg of I/kg) was administered IV, and CT and ultrasonography of the colon were performed. After a 1-week washout period, this process was repeated with a different contrast agent until all agents had been evaluated.

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Table 2—Mean ± SD thickness (mm) of the colon wall of 10 healthy adult Beagles measured in near and far ultrasonographic fields in transverse and longitudinal planes after rectal administration of 3 contrast agents.

Scan plane	Field	Tap water (n = 80)*	Diluted barium (n = 80)*	Room air (n = 80)*
Transverse	Near	1.50 ± 0.56^{a}	1.42 ± 0.36^{b}	1.23 ± 0.47^{c}
	Far	1.61 ± 0.58^{d}	1.36 ± 0.40^{e}	1.28 ± 0.30^{f}
Longitudinal	Near	1.63 ± 0.45^{a}	1.30 ± 0.37^{b}	1.25 ± 0.48^{c}
	Far	1.57 ± 0.63^{d}	1.29 ± 0.50^{e}	1.47 ± 0.22^{f}

$^{a–c}$Within a row, values with different superscript letters differ significantly ($P < 0.001$). $^{d–f}$Within a row, values with different superscript letters differ significantly ($P < 0.05$).

See Table 1 for remainder of key.

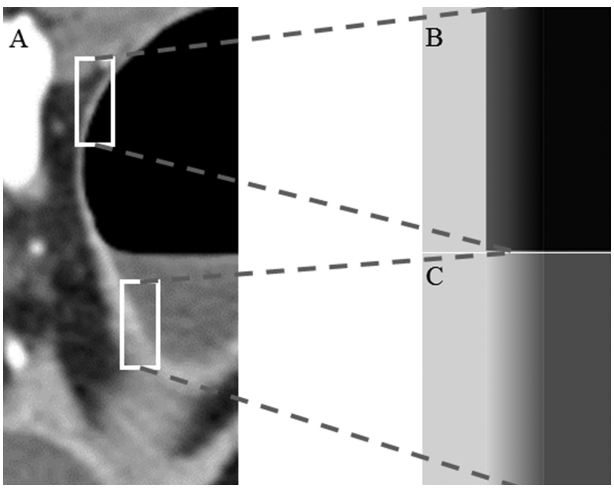

Figure 1—Transverse CT image of the colon wall of a representative healthy adult Beagle (A) and enlarged portions of those images indicating the margin of the wall for the contrast agents room air (B) and tap water (C). Notice that the contrast-enhanced intestinal wall appears thicker for water than for air; because attenuations of the intestinal wall and luminal water were averaged, the margin of the intestinal wall may appear blurred.

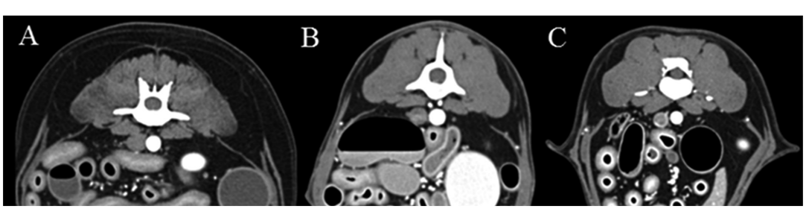

Figure 2—Transverse CT images of the colon of a representative healthy adult Beagle after rectal administration of tap water (A), diluted barium (B), and room air (C). Agents were evaluated separately, with a 1-week washout period provided between evaluations. Notice that conspicuity between the hyperattenuating lumen and colon wall is poor after administration of barium, whereas administration of water and air yield a distinct intestinal wall.

graphic images obtained after rectal administration of tap water, followed by those obtained after rectal administration of diluted barium or room air **(Figures 1–3)**. No significant differences in wall thickness measurements were identified between the 2 investigators.

When dogs were allocated into 2 groups on the basis of body weight, dogs that weighed > 10 kg had a significantly thicker colon wall on both CT and ultrasonographic images than did dogs that weighed < 10 kg **(Table 3)**. No significant difference in wall thickness was identified between values measured on longitudinal ultrasonographic images and those measured on transverse ultrasonographic images.

Conspicuity of the colon wall increased with administration of contrast agents, but the degree of conspicuity differed significantly, depending on the contrast agent **(Tables 4 and 5)**. Rectal administration of tap water resulted in a high conspicuity score for the ventral and dorsal portions of the colon wall on CT images and in the far-field portion of the wall on ultrasonographic images. In the near-field portion of the colon wall during ultrasonography, conspicuity was greatest with barium and least with air. Ultrasonography revealed no significant differences in wall layering among contrast agents.

Artifact scores for CT were significantly ($P < 0.001$) different among contrast agents. Rectal administration of tap water resulted in the lowest mean ± SD artifact score (1.00 ± 0.00), followed by rectal administration of barium (1.01 ± 0.27) and room air (1.01 ± 0.11). Mean ± SD score for lumen dilation of the colon on ultrasonographic images was significantly ($P < 0.001$) greater after rectal administration of barium (2.85 ± 0.42) than for tap water (2.70 ± 0.51) or room air (2.64 ± 0.62), whereas the dilation scores for CT images did not differ significantly among the contrast agents.

When results for CT and ultrasonography were compared, mean ± SD wall thickness measured by use of CT (1.24 ± 0.45 mm) was significantly ($P < 0.001$) less than that measured by use of ultrasonography (1.50 ± 0.39 mm), whereas the mean score for dilation of the colon lumen measured by use of CT (2.86 ± 0.43) was significantly ($P < 0.001$) greater than that measured by use of ultrasonography (2.70 ± 0.53). Mean ± SD conspicuity score for CT images (2.57 ± 0.74) was significantly ($P < 0.001$) greater than that for ultrasonographic images (2.29 ± 0.78), but wall layering was more clearly identified with all 3 contrast agents on ultrasonographic images than on CT images.

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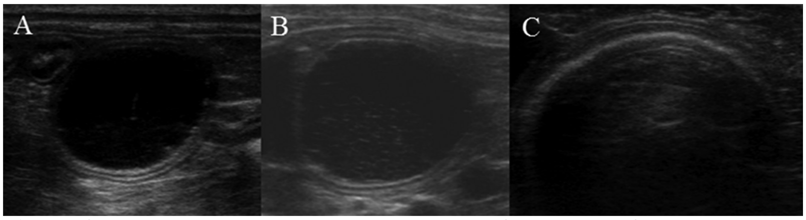

Figure 3—Transverse ultrasonographic images of the colon of a representative healthy Beagle after rectal administration of tap water (A), diluted barium (B), and room air (C). In panel A, notice that water fills the lumen and provides optimal images for evaluation of wall layering. In panel B, barium particles overlay the intestinal wall, which reduces conspicuity of the near-field portion of the colon wall and results in poorer image quality. In panel C, air induces a reverberation artifact; thus, the far-field portion of the colon wall could not be evaluated. ***See*** Figure 2 for remainder of key.

Discussion

In the study reported here, CT and ultrasonographic examinations of the colon were performed without any major adverse effects. Both modalities provided good-quality images for the ascending, transverse, and descending colon of dogs after contrast agents were rectally administered; the intestinal lumen was well dilated and appropriate for estimating thickness of the intestinal wall.

In most dogs, the intestine was easily traced from the ascending colon to the rectum during ultrasonography. Thickness of the colon wall was easily measured by use of CT and ultrasonography after administration of contrast agents, except for the far-field portion of the wall on ultrasonographic images after administration of room air. For each contrast agent, wall thickness measured by use of ultrasonography was significantly greater than that measured by use of CT; however, the mean value measured by use of CT and

Table 3—Mean ± SD thickness (mm) at different aspects of the colon wall of 10 healthy adult Beagles measured by use of CT and ultrasonography, with data grouped on the basis of dog body weight.

Imaging modality	Aspect	< 10 kg (n = 120)*	> 10 kg (n = 120)*
CT	Ventral portion	1.12 ± 0.36[a]	1.35 ± 0.44[b]
	Dorsal portion	0.97 ± 0.37[a]	1.29 ± 0.50[b]
Ultrasonography			
Transverse	Near field	1.40 ± 0.31[a]	1.53 ± 0.42[b]
	Far field	1.49 ± 0.35[a]	1.60 ± 0.46[b]
Longitudinal	Near field	1.38 ± 0.34[c]	1.49 ± 0.47[d]
	Far field	1.54 ± 0.35[c]	1.67 ± 0.49[d]

*The n represents results for 5 dogs, 3 contrast media, 4 sites/dog, and 2 investigators.

[a,b]Within a row, values with different superscript letters differ significantly ($P < 0.001$). [c,d]Within a row, values with different superscript letters differ significantly ($P < 0.05$).

See Table 1 for remainder of key.

Table 4—Mean ± SD conspicuity scores for 2 portions of the colon wall of 10 healthy adult Beagles assessed by use of CT after rectal administration of 3 contrast agents.

Portion	Tap water (n = 80)*	Diluted barium (n = 80)*	Room air (n = 80)*
Ventral	2.99 ± 0.11[a]	1.69 ± 0.76[b]	2.94 ± 0.29[a]
Dorsal	3.00 ± 0.00[a]	1.83 ± 0.79[b]	2.98 ± 0.16[a]

[a,b]Within a row, values with different superscript letters differ significantly ($P < 0.05$).

Conspicuity was scored by use of a 3-point scale (1 = poor, 2 = adequate, and 3 = optimal).

See Table 1 for remainder of key.

Table 5—Mean ± SD conspicuity scores for the colon wall of 10 healthy adult Beagles assessed in near and far ultrasonographic fields after rectal administration of 3 contrast agents.

Field	Tap water (n = 80)*	Diluted barium (n = 80)*	Room air (n = 80)*
Near	2.63 ± 0.55[a]	2.70 ± 0.51[a]	2.54 ± 0.57[a]
Far	2.53 ± 0.59[a]	2.28 ± 0.67[b]	1.06 ± 0.29[c]

[a–c]Within a row, values with different superscript letters differ significantly ($P < 0.001$).

See Tables 1 and 4 for remainder of key.

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ultrasonography was within the anticipated range for thickness of the colon wall (1 to 2 mm).[8] The colon was more fully dilated with contrast agents on CT images than on ultrasonographic images. Therefore, the discrepancy in wall thickness between CT and ultrasonography may have been related to the degree of colon dilation. Wall thickness was measured with minimal change of each anesthetized dog's position. Moreover, leakage of contrast agent was prevented by use of a balloon catheter placed in the rectum. Although obvious leakage of contrast agent was not observed, an insidious leakage of contrast agent may have affected the difference in wall thickness and colon dilation between CT and ultrasonography.

The colon wall was thicker in dogs with a greater body weight, and this result was compatible with that of a study[14] on wall thickness of the stomach, small intestine, and ascending colon of dogs. Wall thickness of the ascending, transverse, and descending colon was not significantly different between ultrasonography and CT, except for thickness of the dorsal aspect of the walls of the ascending, transverse, and descending colon estimated by use of CT.

Contrast agent affected thickness of the colon wall, but all measurements were within reference limits. The wall was thickest when tap water was rectally administered as a contrast agent for both CT and ultrasonography. Considering that the amount of dilation did not differ among contrast agents, other factors (eg, partial volume effect) may have affected the wall thickness in dogs after water administration. The partial volume effect occurs as a result of mean attenuation along the path of the CT beam. When attenuation values for the intestinal wall and luminal water were averaged, the margin of the intestinal wall could be blurred and the estimate increased (ie, a thicker wall).

Tap water administration significantly improved conspicuity between the wall mucosal surface and lumen for both ultrasonography and CT. Barium administration resulted in the lowest wall conspicuity score for CT because it had attenuation similar to or greater than that of the contrast-enhanced intestinal wall. Intestinal gas induced marked shadowing and reverberation artifacts over the far-field portion of the wall, with diminishing conspicuity on ultrasonographic images. Layers of the colon wall could be distinctly identified from the serosa to the mucosa on ultrasonographic images but not on CT images.

Various inflammatory diseases or neoplasia of the large intestine can lead to wall thickening. A top list of differential diagnoses can be built on the basis of information about the maintenance of wall layering and the specific layer with pathological changes. A prominent mucosal layer with increased echogenicity and an unevenly thickened submucosal layer may be related to lymphocytic-plasmacytic enteritis of the small intestine.[8] Thickening of the muscular layer in the small intestine is related to chronic enteritis and lymphosarcoma.[15] On CT images of the small intestine, visibility of the serosal and mucosal layers is enhanced after iodine injection.[14] In the present study, only the enhanced mucosal layer was distinctly identified because the wall of the large intestine was thinner than that of the small intestine.

Clinical application of ultrasonography for diagnosis of conditions affecting the large intestine is unlikely to be widely adopted because of the limited acoustic window caused by artifacts relating to fecal material and gas, particularly with regard to the far-field portion of the colon wall and lumen. Artifacts such as beam hardening can be induced by fecal material with hyperattenuation and by the interface between gas and hyperattenuating feces on CT images. Barium is a material with high density and can deteriorate the quality of ultrasonographic and CT images by creating artifacts. In the present study, a 1.5% solution of barium was used, similar to the solution used in CT colonography of humans,[16] and it did not induce substantial beam-hardening artifacts. However, the diluted barium had attenuation similar to that of the contrast-enhanced intestinal wall; thus, wall conspicuity was poor. Artifacts related to rectal administration of air or water were not observed on CT images.

In humans, contrast ultrasonography of the small intestine by use of orally administered polyethylene glycol solution has been used to diagnose small intestinal disease, with a sensitivity of 100% and specificity of 97%.[17] In that study,[17] the large intestine was not dilated well, so hydrocolonic ultrasonography via the anus was used to diagnose and stage colonic tumors. Similarly, contrast agents administered orally can fully dilate the stomach and small intestine in veterinary patients, but not sufficiently to enable evaluation of the wall layers and lumen of the large intestine.[14] To improve imaging of the large intestine, retrograde administration of contrast agents (air, water, and microbubble fluid) has been attempted in veterinary medicine,[11,12] but this technique is not routinely used to diagnose large intestinal diseases in practice settings because of the difficulties with administering enemas and imaging of the colon lumen with a uniform distribution of contrast agent.

In the present study, oral administration of polyethylene glycol electrolyte solution was easily performed, and contrast-enhanced CT images with dogs positioned in sternal recumbency with the cranial portion of the body lower than the caudal portion were optimal for uniform distribution and filling of the colon with contrast agents. In particular, rectal administration of water with IV administration of iodine contrast agent yielded a greater conspicuity score at most of the 4 sites of the colon and a lower artifact score on CT images, and it also provided good acoustic windows for ultrasonography.

The present study had some limitations. A previously reported[8] reference limit on thickness of the colon wall was used instead of histologic examination of the colon; accuracy of measurement of wall

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thickness for each contrast agent was not assessed. The volume of contrast agent administered rectally for CT of the colon has not been studied in veterinary medicine; for the study reported here, the administered volume was determined from a previous pneumocolonography study.[18] Further studies on the optimal volume of contrast agent for rectal administration are needed.

In the present study, rectally administered tap water was used as a contrast agent for CT and ultrasonography of the colon, and it provided images that were clearer than those obtained with rectally administered diluted barium or room air. In addition, water administration resulted in few artifacts. Both ultrasonography and CT have advantages for evaluation of the colon. Hydroultrasonography was good for evaluation of intestinal wall layering, and CT examination of the colon after rectal administration of water and IV administration of iodine contrast agent was effective for evaluation of the overall intestinal lumen and wall. Thus, CT and ultrasonography could be used as complementary methods. When water is used for rectal administration and filling of the colon of dogs, both CT and ultrasonography could be performed.

Acknowledgments

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Footnotes

a. Colyte, Taejoon Pharmaceutical Co, Seoul, Korea.
b. Zoletil, Virbac, Carros, France.
c. Domitor, Orion Corp, Espoo, Finland.
d. Omnihexol 300, Korea United Pharm Co, Sungnam, Korea.
e. Siemens Emotion 16, Siemens, Forchheim, Germany.
f. ProSound Alpha 7, Hitachi-Aloka, Tokyo, Japan.
g. SPSS for Windows, release 22.0, standard version, SPSS Inc, Chicago, Ill.

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