Contrast-enhanced computed tomography of the gastrointestinal tract in clinically normal alpacas and llamas

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Objective—To assess the feasibility and usefulness of CT enterography to evaluate the gastrointestinal tract in clinically normal llamas and alpacas.

Design—Prospective observational study.

Animals—7 clinically normal alpacas and 8 clinically normal llamas.

Procedures—The imaging protocol included orogastric administration of iodinated contrast material mixed with water. Three hours later, helical CT scanning was performed of the entire abdomen with transverse and multiplanar sagittal and dorsal projections before and after IV iodinated contrast agent injection.

Results—Both oral and IV contrast agents were well tolerated, and no adverse reactions were observed. Transverse images depicted the gastrointestinal tract and pancreas in the short axis; however, dorsal and sagittal projections aided in localizing and differentiating the various gastrointestinal segments, including the pancreas. In all camelids, the wall of the gastrointestinal tract was well differentiated. In all but 2 camelids, all gastrointestinal segments were well visualized and differentiated. In those 2 animals, the cecum was difficult to identify. Good distention of the small intestine was achieved by use of the oral contrast agent. The dorsal projections were useful to identify the pancreas in its entire length.

Conclusions and Clinical Relevance—The present study supplied new information about gastrointestinal wall thickness, intestinal diameter, and location of the pancreas and ileocecocolic junction in alpacas and llamas. Multiplanar contrast-enhanced CT was useful to reveal the various segments of the gastrointestinal tract, pancreas, and abdominal lymph nodes. The shorter time delay before imaging, compared with the delay with conventional barium studies, makes this technique complementary or superior to conventional radiographic or ultrasonographic studies for evaluation of the gastrointestinal tract. (*J Am Vet Med Assoc* 2013;242:254–260)

Acute or chronic abdominal pain in llamas and alpacas can present a challenging workup for the attending veterinarian. Clinical findings can be nonspecific, and the differential diagnoses can vary from self-limiting to life-threatening abdominal pathological changes requiring immediate attention.[1,2] Imaging the gastrointestinal tract has proven to be a valuable part of the assessment of llamas and alpacas with signs of pain, but has limitations: conventional radiographic and ultrasound techniques are limited by the size of the animals and by the presence of gas or feed material within the gastrointestinal tract.[3–6] Endoscopic evaluation cannot usually provide information on the tract aboral to the first gastric compartment or adoral to the descending colon. Cross-sectional imaging techniques such as CT and MRI have advantages over conventional ultrasonography and radiography or even contrast fluoroscopy in their ability to better differentiate superimposed bowel loops and to improve visualization of extraluminal findings and complications.[7,8] In small animals and humans, CT is used extensively to evaluate the abdomen, but reports[9] of its use to evaluate the intestines, especially the intestinal wall, are rare in the veterinary medical literature. With the development of new multidetector row helical CT scanners, faster scan times and isotropic spatial resolution are possible, which allow for high-resolution multiphasic and multiplanar evaluation of the gastrointestinal tract, gastrointestinal wall, and lumen. Conventional positive-attenuation oral contrast media such as barium- or iodine-based agents are used for evaluation of the gastrointestinal tract in veterinary patients, usually via radiography or fluoroscopy. Neutral-attenuation oral contrast agents have an attenuation close to water and commonly used agents include water, milk, polyethylene glycol, 12.5% corn-oil emulsion, and methylcellulose. Conventional positive-attenuation oral contrast agents allow visualization of mucosal detail, whereas neutral-attenuation oral contrast media allow for distension the small intestine and assessment of mucosal enhancement in humans.[10–12]

Considering the advantages of CT, we designed a CT enterography protocol for camelids to allow evaluation of the gastrointestinal structures shortly after ingestion of oral contrast and administration of IV contrast. In the study reported here, we evaluated the feasibility and

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usefulness of CT enterography to optimally enhance the bowel and to differentiate the segments and walls of the gastrointestinal tract in clinically normal llamas and alpacas.

Materials and Methods

Animals—Seven clinically normal alpacas with a mean age of 9.2 years (median, 9 years; range, 13 months to 18 years) and 8 healthy llamas with a mean age of 16 years (median, 16.95 years; range, 11 to 19.3 years) were included in this study. All study animals were clinically normal, on the basis of results of physical examination. No parasites were found on a recent parasite testing, and no previous history existed of gastrointestinal disease. The alpacas weighed from 43 to 94 kg (94.6 to 206.8 lb; median, 81.8 kg [180.0 lb]) and consisted of 1 sexually intact female, 5 neutered males and 1 sexually intact male. The llamas ranged in weight from 121 to 173 kg (266.2 to 380.6 lb; median, 161.1 kg [354.4 lb]) and included 3 sexually intact females, 3 sexually intact males, and 2 neutered males. Feed was withheld from all animals for 12 hours before a CT enterography was performed. The study was approved by the Oregon State University Institutional Animal Care and Use Committee. For privately owned camelids, written consent was obtained from all owners prior to the study.

Multislice CT protocol—All CT examinations were performed with a 64-slice CT scanner.[a] Three hours before the CT enterography, animals were administered via an orogastric tube a high-concentration oral iodinated contrast agent containing diatrizoate meglumine and diatrizoate sodium solution[b] mixed with water. Animals ≤ 100 kg (220 lb) received 60 mL of the oral iodinated contrast agent mixed in 750 mL of water; animals > 100 kg received 120 mL of the agent in 1,200 mL of water. These volumes were adapted from human dosages and estimated on the basis of clinical experience of transit time of oral iodinated contrast agents in other species. Three hours after oral contrast agent administration, animals were sedated with butorphanol tartrate[c] (0.1 mg/kg [0.05 mg/lb], IM), and a jugular catheter was placed. After IV catheter placement, the animals were moved to the CT examination room, anesthetized by means of diazepam[c] (0.25 mg/kg [0.11 mg/lb], IV) and ketamine[d] (0.3 mg/kg [0.14 mg/lb], IV), and placed in sternal recumbency on the CT examination table. An abdominal CT scan was obtained from the cranial border of the diaphragmatic cupola to the caudal border of the anus. Subsequently, IV contrast-enhanced CT was performed after IV injection of 1 mL of iopamidol[e]/kg (0.5 ml/lb) via a power injector[f] at a flow rate of 3 mL/s. Scanning was performed 60 seconds after initiation of the contrast injection, which corresponded to the venous phase. The animals were scanned with a tube voltage ranging from120 to 135 kVp, a tube current of 245 to 400 mA, a helical pitch of 53, a pitch factor of 0.828, and a slice thickness of 0.5 mm. The thin collimated CT volume data were used to create transverse, dorsal, and sagittal reconstructed images of the abdomen with 3-mm slice thickness.

After the CT examination, animals were allowed to recover from anesthesia, and once they were fully awake, they were observed for another 6 hours, which included regular physical examinations, before they were discharged from the hospital. Four of the 15 animals were euthanized for reasons unrelated to this study, and histologic evaluations were performed, which included samples from all 3 compartments of the stomach, small and large intestine, pancreas, lymph nodes, and representative samples of other organ systems.

Image analysis—A DICOM (ie, Digital Imaging and Communications in Medicine) viewer[g] was used to view and perform measurements of the gastrointestinal wall thickness, maximum diameter of the third compartment, small intestine, spiral colon, descending colon and rectum, and the maximum height and length of the second lumbar vertebra on the contrast-enhanced images. Transverse images were used to measure the wall thickness of the first, second, and non–acid-secreting third compartments of the stomach; the small intestine; and the spiral colon. The wall thicknesses of the acid-secreting third compartment of the stomach, descending colon, and rectum were measured on sagittal images. For each wall thickness measurement, 3 areas of the well-distended organ were identified and measured, and mean values were obtained. Additionally, the maximum height and length of the second lumbar vertebra was measured on a midline sagittal image. The gastrointestinal wall thickness and diameter were measured in a soft tissue window (window width, 400 Hounsfield units; window level, 40 Hounsfield units), and the second lumbar vertebra was measured in a bone window (window width, 2,700 Hounsfield units; window level, 350 Hounsfield units). Furthermore, the contents of the gastrointestinal tract; the presence of gastroliths, enteroliths, or both; the location of the pancreas and cecum; and the distal extent of the oral contrast agent were described.

Statistical analysis—Data were tested for normality by means of the D'Agostino and Pearson omnibus normality test. All results were expressed as mean ± SD, median, and range. Wall thickness and gastrointestinal diameter measurements were compared between alpacas and llamas by means of a Student *t* test. To account for the difference in body size between llamas and alpacas and intraspecies variation, diameter comparisons were repeated via a ratio calculated by dividing the mean diameter of the gastrointestinal tract by the maximum height of the second lumbar vertebral body. For all tests, significance was set at a level of $P < 0.05$.

Results

Computed tomography examinations were performed without complications in all animals. No adverse reactions to the oral or IV iodinated contrast agent were observed. No abnormality of the gastrointestinal tract was observed in any of the animals as determined by CT. None of the 4 animals that were euthanized had abnormal histologic findings on examination of the gastrointestinal tract.

Anatomic location—The first gastric compartment was caudal to the diaphragm in the left cranial abdomen. The esophagus crossed the diaphragm near

midline and followed the right wall of the first gastric compartment before entering it. The first gastric compartment extended from the diaphragm caudally into the left flank (**Figures 1 and 2**). The cranial glandular saccular region of the first gastric compartment extended between the second and third gastric compartments in the right cranial abdomen. The caudal saccular region was located along the right caudoventral wall of the first gastric compartment. The cranial aspect of the second gastric compartment began cranioventrally adjacent to the apex of the heart, slightly cranial and to the right of the first gastric compartment. The second gastric compartment then extended caudally along the right side of the first gastric compartment into the third gastric compartment. The second gastric compartment extended from the level of the eighth to the ninth thoracic vertebra. The second gastric compartment had a characteristic pattern with triangular to half-moon–shaped, gas-filled areas in its center. The body of the third gastric compartment traveled in a straight path along the right abdominal wall, caudomedial to the liver. At the level of the third to fifth lumbar vertebra, the third gastric compartment turned 180° in a craniodorsal direction (**Figure 3**). After this caudal flexure, the third gastric compartment widened, then narrowed at the pylorus. In the ventral aspect of the terminus of the third gastric compartment, a prominent triangular to ovoid-shaped torus pyloricus was present, which separated the third gastric compartment from the ampulla duodeni.

The small intestine was seen caudal and medial the third gastric compartment in the central and caudal abdomen. The small intestine extended in some animals caudally into the pelvic canal, ventral to the descending colon and urinary bladder (Figures 1 and 3). In these animals, the small intestine extended to the caudal border of the ischiatic table. In the sagittal view, the small intestine tended to lie ventral to the colon and against the ventral abdominal wall. In 6 of the 7 alpacas and 7 of the 8 llamas, the ileocecocolic junction was on or slightly to the right of the midline. In 1 alpaca and 1 llama, the ileocecocolic junction and cecum could not be clearly identi-

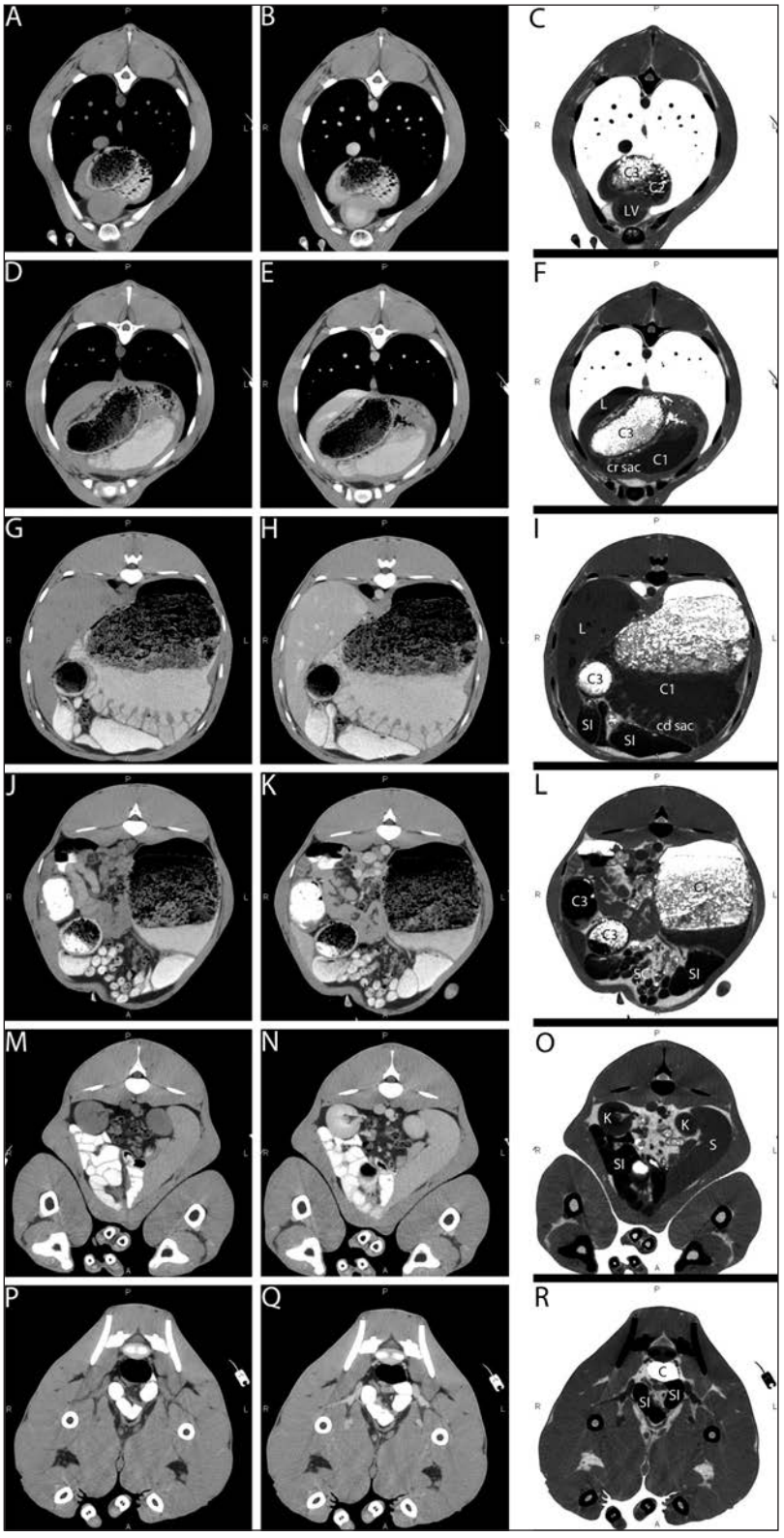

Figure 1—Transverse CT images (soft tissue window) of the abdomen of a clinically normal 1.1-year-old male alpaca. The images are arranged from cranial to caudal in the abdomen. The images in panels A, D, G, J, M, and P were obtained prior to IV iodinated contrast agent administration, and the images in panels B, E, H, K, N, and Q are the corresponding images after IV iodinated contrast administration with a 60-second delay. Panels C, F, I, L, O, and R are the corresponding black-and-white inverted images of the first column. C = Colon. C1 = First compartment of the stomach. C2 = Second compartment of the stomach. C3 = Third compartment of the stomach. cd sac = Caudal glandular saccules of the first compartment of the stomach. cr sac = Cranial glandular saccules of the first compartment of the stomach. K = Kidney. L = Liver. S = Spleen. SC = Spiral colon. SI = Small intestine.

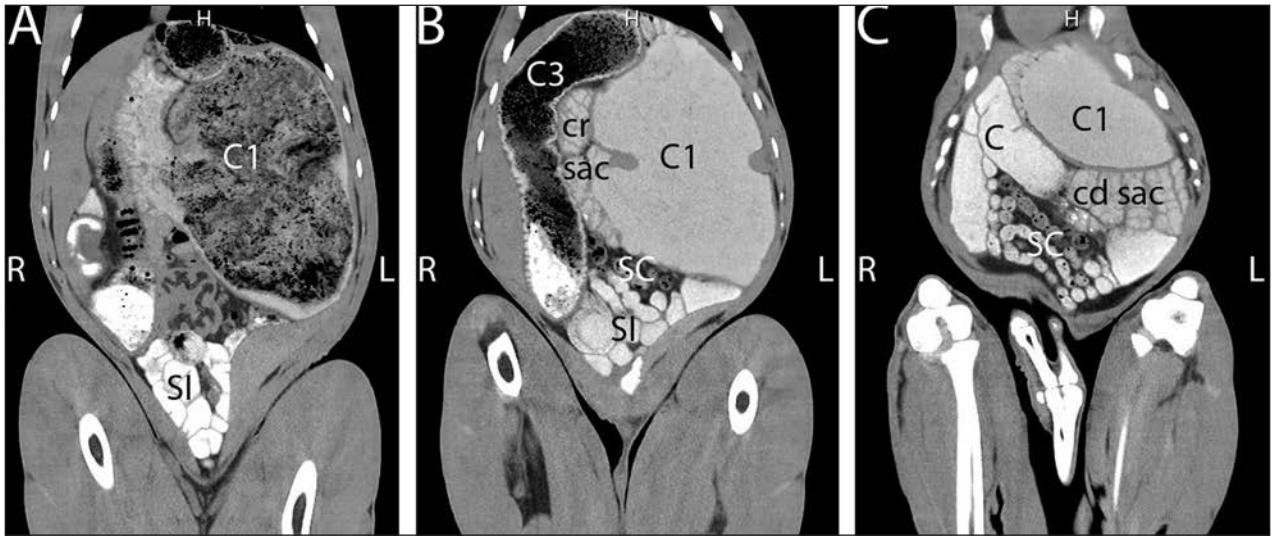

Figure 2—Dorsal CT images (soft tissue window) of the abdomen of the same animal as in Figure 1. Panels show the dorsal (A), middle (B), and ventral (C) aspects of the abdomen. H = CT-specific denotation marking the direction of the head of the animal. *See* Figure 1 for remainder of key.

fied. In 5 alpacas, the cecum lay to the right of midline, and in 1 alpaca, it was on the left. In 4 llamas, the cecum was on the left, and in 3 llamas, it was on the right. The ascending colon lay medial to the third gastric compartment and the small intestine in the middle to caudal abdomen. The spiral colon tended to be central and to the left of midline caudal to the first gastric compartment and medial to the spleen (Figure 2). The descending colon was seen in all animals in the left dorsal aspect of the abdomen traversing caudally into the pelvic canal.

Gastrointestinal wall thickness—No significant difference between alpacas and llamas was identified in any of the wall thickness measurements of the gastrointestinal segments (**Table 1**). The thickness of the wall of the 3 compartments of the stomach ranged from 1 to 9 mm in alpacas and from 1 to 8 mm in llamas. The thickest wall identified in both species was in the caudoventral acid-secreting aspect of the third gastric compartment. The torus pyloricus was also thick (20.7 ± 2.2 mm [median, 21 mm; range, 16 to 24 mm] in alpacas and 20.9 ± 5.2 mm [median, 19 mm; range, 15 to 29 mm] in llamas), as was the wall opposite the torus (7.0 ± 4.3 mm [median, 5 mm; range, 4 to 19 mm] in alpacas and 7.6 ± 3.5 mm [median, 7 mm; range, 2 to 15 mm] in llamas). The thinnest walls identified (1 to 2 mm) were in the ampulla duodeni, small intestine, and spiral colon.

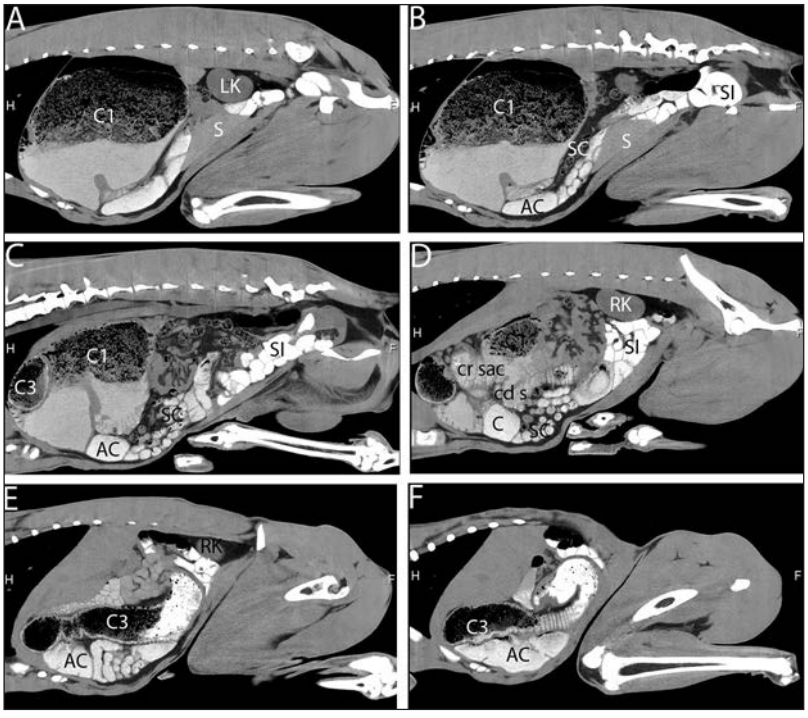

Figure 3—Sagittal CT images (soft tissue window) of the abdomen of the same animal as in Figure 1. Panels A to F are from left to right through the abdomen. AC = Ascending colon. LK = Left kidney. RK = Right kidney. *See* Figures 1 and 2 for remainder of key.

Intestinal diameter—No significant difference between the means of the gastrointestinal diameters between llamas and alpacas was observed. The intestinal diameter tended to be slightly larger in llamas than in alpacas. The difference between the means of the intestinal diameters between alpacas and llamas was < 4 mm (**Table 2**).

No significant differences in the ratios of organ diameter to second lumbar vertebral body height were identified. In both species, the smallest ratio was observed in the spiral colon, followed by the small intestine. The largest range in diameter and ratio was seen in the descending colon and rectum (Tables 2 and 3).

Content of the gastrointestinal tract—In the first gastric compartment, the contrast material pooled

Table 1—Gastrointestinal wall thickness (mm) obtained via CT* in 7 clinically normal alpacas and 8 llamas.

	Gastrointestinal wall thickness (mm)					
	Alpaca (n = 7)			Llama (n = 8)		
Region	Mean ± SD	Median	Range	Mean ± SD	Median	Range
First gastric compartment	3.3 ± 1.2	3	1–5	4.3 ± 1.4	4	2–7
Second gastric compartment	3.3 ± 1.2	3	1–6	2.9 ± 1.6	2.5	1–6
Third gastric compartment (non–acid secreting)	3.1 ± 0.7	3	2–4	3.3 ± 0.9	3	2–4
Third gastric compartment (acid secreting)	6.0 ± 1.3	6	3–9	5.5 ± 1.6	5.5	3–8
Ampulla of duodenum	1.1 ± 0.4	1	1–2	1.2 ± 0.4	1	1–2
Small intestine	1.2 ± 0.4	1	1–2	1.1 ± 0.3	1	1–2
Spiral colon	1.4 ± 0.5	1	1–2	1.5 ± 0.6	1	1–2
Rectum	1.4 ± 0.7	1	1–3	1.4 ± 0.6	1	1–3

*Three hours before CT enterography, animals were administered via an orogastric tube a high-concentration oral iodinated contrast agent containing diatrizoate meglumine and diatrizoate sodium solution[b] mixed with water. Animals ≤ 100 kg (220 lb) received 60 mL of the oral iodinated contrast agent mixed in 750 mL of water; animals > 100 kg received 120 mL of the agent in 1,200 mL of water. An abdominal CT scan was performed from the cranial border of the diaphragmatic cupola to the caudal border of the anus, followed by an IV contrast-enhanced CT scan of the same area with a 60-second delay. Images were analyzed off-line with a DICOM (ie, Digital Imaging and Communications in Medicine) viewer, and measurements of the wall thickness and intestinal diameter of the various segments of the gastrointestinal tract were performed.

Table 2—Gastrointestinal diameter (cm) obtained via CT* in 7 clinically normal alpacas and 8 llamas.

	Gastrointestinal diameter (mm)					
	Alpaca (n = 7)			Llama (n = 8)		
Region	Mean ± SD	Median	Range	Mean ± SD	Median	Range
Third gastric compartment (non–acid secreting)	5.1 ± 0.9	5.1	3.7–7.6	6.3 ± 0.8	6.3	4.3–7.9
Small intestine	1.8 ± 0.4	1.9	1.1–2.7	2.2 ± 0.6	2.2	1.0–3.5
Spiral colon	1.2 ± 0.3	1.2	0.7–1.7	1.4 ± 0.3	1.5	0.8–2.1
Descending colon	3.5 ± 0.9	3.2	2.1–5.5	4.1 ± 1.3	4.0	1.8–6.7
Rectum	3.1 ± 1.4	3.0	1.1–5.8	4.2 ± 1.0	4.1	1.7–6.1

See Table 1 for key.

Table 3—Ratio of the gastrointestinal diameter divided by the maximum height of the second lumbar vertebral body obtained via CT* in 7 clinically normal alpacas and 8 llamas.

	Gastrointestinal diameter divided by the maximum height of the vertebral body of L2					
	Alpaca (n = 7)			Llama (n = 8)		
Region	Mean ± SD	Median	Range	Mean ± SD	Median	Range
Third gastric compartment (non–acid secreting)	2.7 ± 0.5	2.6	1.9–3.8	2.7 ± 0.4	2.8	1.8–3.0
Small intestine	1.0 ± 0.2	1.0	0.6–1.4	1.0 ± 0.3	0.9	0.4–1.5
Spiral colon	0.6 ± 0.1	0.7	0.4–0.9	0.6 ± 0.2	0.6	0.3–0.9
Descending colon	1.9 ± 0.6	1.7	1.1–3.4	1.8 ± 0.6	1.8	0.8–2.8
Rectum	1.6 ± 0.7	1.5	0.6–3.1	1.8 ± 0.4	1.7	0.7–2.7

See Table 1 for key.

ventrally, covered by a layer of fibrous feed material. Dorsally, there was a gas cap. The cranial glandular saccules of the first gastric compartment contained a lower number of various-sized and -shaped mineral densities, compared with the caudal glandular saccules. The second gastric compartment contained coarse fiber-like material similar to the first gastric compartment, but no gas cap was present. The third gastric compartment contained loosely packed fibrous material and gas. The duodenal ampulla contained mostly fluid and, in a few animals, a small amount of fibrous material. The small intestine had fluid contents. The ascending colon, spiral colon, and descending colon showed small quantities of fiber-like material mixed with gas. The material was loosely packed. The cecum contained variable amounts of fluid and gas.

Oral contrast agent transport and IV contrast enhancement of the gastrointestinal tract—No complications were observed associated with either gastroenteral or IV iodinated contrast administration. In all llamas and alpacas, the oral contrast agent was clearly identifiable in the gastric compartments and small intestines up to the ileocecocolic junction. In all animals (13/15) where the cecum was identified, variable amounts of contrast were present in the cecum. Good contrast fill-

ing and distension of the small intestine were achieved by means of oral contrast mixed with water. In 3 llamas, the contrast was already present in the spiral colon 3 hours after orogastric intubation.

Sixty seconds after IV contrast administration, good contrast enhancement of the gastrointestinal walls was present. Mucosal enhancement was seen after oral contrast administration. Intravenous contrast administration enhanced the mucosal enhancement. No or very mild contrast enhancement of the outer wall layers was present. Intravenous contrast administration helped to differentiate the gastrointestinal wall from the gastrointestinal contents.

Imaging and location of the pancreas—In all camelids, the pancreas could be visualized. The pancreas was best outlined in the dorsal reconstructed images at the level of the pancreas (**Figure 4**). The pancreas had a V shape, with the left lobe being longer than the right. The pancreatic body was located in the angle between the caudal aspect of the liver and right medial side of the first gastric compartment at the caudal and right side of the portal vein just before it entered the liver and divided. The right lobe of the pancreas traveled for a very short distance caudally on the medial side of a loop of small intestine, possibly duodenum. The left lobe could be identified along the caudal border of the first gastric compartment on the right medial side of the portal vein traveling in an oblique fashion across the cranial abdomen on the left side of a splenic vein caudally. The left lobe of the pancreas extended caudally to the triangle formed by the caudal aspect of the spleen and cranial aspect of the left kidney. After IV contrast administration, a mild, homogenous, generalized contrast enhancement of the pancreas was present.

Other abdominal structures—Several small lymph nodes (portal and mesenteric) were identified in the abdomen. The kidneys and adrenal glands were well visualized. Dorsal reconstructed views helped to outline the adrenal glands. The uterus and, in 4 of 5 female animals, the ovaries were well visualized. Sagittal and dorsal reconstructions helped to outline the uterus and ovaries. The urinary bladder was easily seen in all animals.

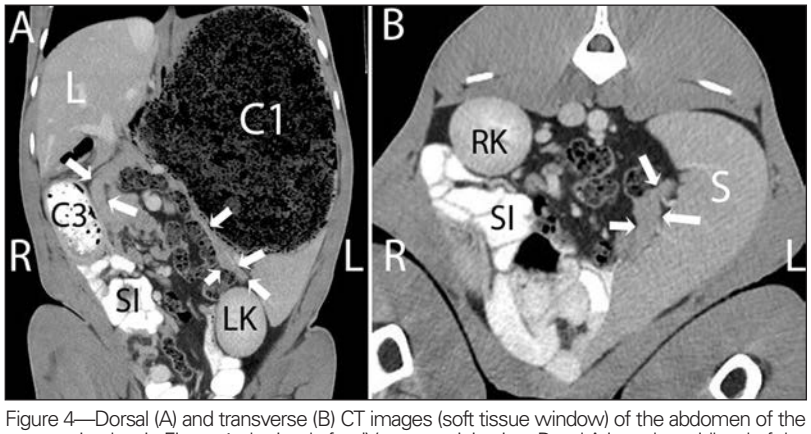

Figure 4—Dorsal (A) and transverse (B) CT images (soft tissue window) of the abdomen of the same animal as in Figure 1 obtained after IV contrast injection. Panel A is at the midlevel of the left kidney, and panel B is at the level of the cranial pole of the right kidney. The arrows in both images outline the mildly contrast-enhanced pancreas. *See* Figures 1 and 3 for remainder of key.

Discussion

Double contrast-enhanced CT allowed rapid evaluation of the entire gastrointestinal tract of llamas and alpacas, providing excellent 3-D information on a variety of organs. These were found in the same anatomic locations as described in previous reports,[9,13] as recorded by use of CT or other imaging techniques. Interestingly, despite the size difference between alpacas and llamas, no significant difference was observed in gastrointestinal wall thickness or intestinal diameter.

The obtained images were of considerably higher spatial resolution than in an earlier CT report,[8] most likely because of technological advances, including a multidetector row scanner, improved algorithms, and the contrast agent protocol. The high spatial resolution of the scanner and the ability to perform sagittal and dorsal reconstructions in the present study also allowed evaluation of organs otherwise difficult to image. These included the pancreas, adrenal glands, and abdominal lymph nodes. We are unaware of any previous imaging description of the location and appearance of the entire pancreas or adrenal glands in camelids.

The use of the oral iodinated contrast agent to enhance CT has not been reported previously in the veterinary medical literature, to our knowledge. This technique is common in CT imaging of humans with disorders of the esophagus, stomach, proximal small intestine, and colon.[11] In the first gastric compartment, the contrast agent pooled ventrally, under dorsal layers of fibrous food material and gas. This was similar to what is seen with oral barium sulfate in llamas.[9] In the small intestine, it achieved good distension and demarcation of walls. Gastric and intestinal diameters and wall thickness could be measured easily and appeared comparable to results obtained from ultrasonographic studies.[2] The contrast appearance and appearance of the wall of the small intestine and spiral colon were also substantially different from each other and easy to differentiate. In a previous study,[9] laparoscopic injection of contrast directly into the spiral colon was necessary for this differentiation. In most of the animals of the present study, the cecum could be distinctly identified and evaluated as well. Thus, use of this oral contrast protocol allowed better examination of organs than has previously been reported.[9]

Additionally, in comparison to a previous study,[9] the transit time of the iodinated oral contrast agent was substantially faster than that of barium sulfate solution, and therefore, earlier scanning of the patient was possible. Earlier scanning after oral contrast administration will allow evaluation of patients with gastrointestinal disease without long waiting periods as the iodinated contrast agent rapidly transits through the gastrointestinal tract.

The shorter imaging acquisition times also allowed CT to be performed under short-acting sedation. General anesthesia was used in most previous studies,[8] but may be detrimental in compro-

mised patients. The short duration of anesthesia also allowed the studies to be performed without endotracheal intubation. This could be considered risky because camelids are thought to be prone to regurgitation and aspiration of gastric contents. However, this was not seen in any of the camelids in the present study. The animals in this study consisted of healthy camelids from which food had been withheld for 12 hours and that were positioned in sternal recumbency, which likely reduced the risk for regurgitation or aspiration. In sick camelids, particularly those with poor gastric emptying or those that have eaten or drank recently, endotracheal intubation may be advisable, if extended anesthesia times are expected.

In comparison with transabdominal ultrasonography for evaluation of the gastrointestinal tract, the contrast-enhanced CT protocol in the present study allowed a more complete evaluation of all abdominal viscera and provided more extensive 3-D information. Distinct advantages over ultrasonography also included the rapid acquisition of all data and the ability to determine with certainty that the correct segment of the gastrointestinal tract was being evaluated and measured. Ultrasonography is limited by depth penetration, the interference of overlying viscera, and the presence of gas in the gastrointestinal tract, none of which impede abdominal CT. Ultrasonography allows direct evaluation of intestinal motility,[2] which is not possible with CT, but motility could be inferred by the passage of the oral contrast agent. It is expected that if peristalsis were reduced or lacking, the oral contrast agent would be retained in the stomach or proximal small intestine.

In this study, no adverse reactions to the oral or IV contrast agent were observed. Both were well tolerated. It is important to ensure that an animal is well hydrated before contrast agent use. All animals included in the study were well hydrated; in addition, the orogastric administration of water in combination with the contrast agent before the CT scan provided a good hydration status of the animals in this study. The CT enterography worked well in camelids, and it might be possible to adapt this protocol to other species.

Limitations of CT enterography, in comparison with ultrasonography (a more commonly used technique to evaluate the abdomen in camelids), are the necessity for orogastric intubation to administer the contrast agent and the requirement for sedation. As the animals of this study were sedated after orogastric contrast application just before the CT examination was performed, and as our scan times were so short, we likely did not seen an effect of sedation on gastric motility while the patient was scanned; however, gastric motility might be affected by the type of sedation used. This might especially be important to consider in diseased animals with already impaired gastric motility.

Computed tomography of the camelid gastrointestinal tract is a very useful imaging technique on the basis of the superior anatomic information it provides, the lack of invasiveness, and the ability to be performed in a timely manner with patients under sedation. Contrast-enhanced CT of the abdomen may have diagnostic benefits in the evaluation of camelid patients with colic or gastrointestinal disease, but further investigation is needed.

a. Aquillion 64, Toshiba America Medical Systems Inc, Tustin, Calif.
b. Gastrografin, Bracco, Princeton, NJ.
c. Hospira Inc, Lake Forest, Ill.
d. Ketaset, Fort Dodge Animal Health, Fort Dodge, Iowa.
e. Bracco, Princeton, NJ.
f. Empower CTA contrast injection system, ACIST Medical Systems Inc, Eden Prairie, Minn.
g. eFilm, Merge Healthcare, Heartland, Wis.

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