FEASIBILITY FOR USING DUAL-PHASE CONTRAST-ENHANCED MULTI-DETECTOR HELICAL COMPUTED TOMOGRAPHY TO EVALUATE AWAKE AND SEDATED DOGS WITH ACUTE ABDOMINAL SIGNS

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Canine patients with acute abdominal signs are often clinically unstable and need a rapid and accurate diagnosis. Contrast-enhanced multi-detector computed tomography (CT) is the current modality of choice for evaluating acute abdominal pain in people. We hypothesized that contrast-enhanced multi-detector CT would be a feasible and safe technique for use in awake and lightly sedated dogs with acute abdominal signs. Eighteen client-owned dogs were enrolled, all presenting with acute abdominal signs. Dogs were scanned using a dual-phase protocol that included precontrast, arterial, and portal venous phases. Eight dogs were scanned awake and ten were given light sedation as chosen by the primary care clinician. Two observers who were unaware of clinical findings and sedation status scored image quality for each scan by consensus opinion. Mean serum creatinine in the sedated group was higher than in the awake group but was within the normal reference range. Other laboratory and physiologic measures did not differ between awake and sedated groups. No IV contrast-related adverse reactions were seen. Median scan time for all patients was less than 10 min. Sixteen of 18 contrast-enhanced multi-detector CT scans were scored fair to excellent in diagnostic quality, with no statistical difference in diagnostic quality for awake vs. sedated patients. Causes for two poor quality diagnostic scans included severe beam hardening from previously administered barium contrast agent and severe motion artifacts. We conclude that dual-phase contrast-enhanced multi-detector CT is a feasible and safe technique for evaluating awake and minimally sedated dogs presenting with acute abdominal signs.

Key words: acute abdomen, awake, dog, MDCT.

Introduction

ACUTE ABDOMINAL PAIN IN the small animal patient may be minor and transient or the result of an immediately life-threatening process. Specific injury or disease of the peritoneal or retroperitoneal structures, diaphragm, or body wall constituents constitute the majority of underlying etiologies, although referred pain from other sites, (especially the spine) may also be mistaken for abdominal pain.[1] Survey radiography and routine B-mode abdominal ultrasound (US) are the conventional imaging techniques used in the small animal emergency setting, and are characterized by multiple limitations. With the exception of the identification of spontaneous pneumoperitoneum, survey radiographic findings are often nonspecific. As a result, routine abdominal US is often performed in conjunction with the added advantage of elimination of visceral superimposition and ability to evaluate parenchymal detail. Limitations of abdominal US in small animal patients with acute abdominal pain include interference by bowel gas, patient discomfort, interoperator variability, and long scan times.

Targeted helical computed tomography (CT) of the abdomen has been described as the modality of choice in people with acute abdominal pain.[2–4] Multi-detector helical CT advantages include relative rapidity of image acquisition and high spatial resolution. In cases with nonlocalizable abdominal pain, a contrast-enhanced single portal venous phase protocol has been proposed and a dual-phase acquisition has been recommended for patients with suspected acute pancreatitis.[3]

Reports describing CT evaluation of the canine abdomen have increased during the past decade. Applications include suspected disease of the upper and lower urinary tract,[5–11] spleen,[12,13] hepatic/portal venous system,[14–26] pancreas,[27–29] mesenteric/intrapelvic regions,[30,31] adrenal gland,[32–34] and gastrointestinal tract.[35,36] These reports primarily describe the use of anesthesia or heavy sedation during scan procedures in order to minimize motion artifacts that could result in nondiagnostic scans. Given the recent success of awake imaging protocols for evaluating

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small animal upper airway and intrathoracic diseases,[37–39] we hypothesized that dual-phase contrast-enhanced multidetector computed tomography (MDCT) would be feasible and safe for use in awake and lightly sedated canine patients with acute abdominal signs.

Materials and Methods

All protocols were approved by the institutional animal care and use committee of the University of Illinois. Eighteen client-owned dogs presented to the University of Illinois Veterinary Teaching Hospital between February 2011 and January 2012 for acute abdominal signs were enrolled. Study inclusion criteria were cytologic, survey radiographic, and/or sonographic detection of a condition requiring immediate surgical intervention (visceral abscess, spontaneous pneumoperitoneum, or small intestinal mechanical obstruction); or a sonographic abnormality consistent with acute pancreatitis[27,40–45] or gastrointestinal neoplasia.[46–50] Study inclusion was based on the opinion of a board-certified veterinary radiologist and/or radiology resident under the supervision of a board-certified veterinary radiologist. An attempt was made to scan patients awake first, and minimal IV sedation was used when there was poor patient cooperation or evidence of discomfort. Sedation protocols consisted of an opioid with or without addition of a benzodiazepine administered intravenously as a bolus or continuous rate infusion. Specific drug and dosage combinations were selected by the primary care clinician and are summarized in Table 1.

All patients underwent dual-phase contrast-enhanced abdominal CT using a 16-slice helical CT scanner* and the following technique settings: kV 120, mA ranging from 200–325, slice width 2.5 mm with 1.25 mm overlap, pitch 0.9:1 or 1.3:1, and rotation time 0.5 s. A dose of 2 ml/kg (600 mg I/kg) of nonionic iodinated contrast medium† was administered intravenously in all patients with the exception of two of the large breed dogs (Boxer and Bloodhound) that received a maximum of 60 ml (1.6 ml/kg and 1 ml/kg, respectively). The contrast agent was administered as a hand-injected fast bolus in patients weighing $\leq$ 20 lbs. In patients weighing $\geq$ 20 lbs, the contrast agent was administered via power injector at a rate of 3 ml/s followed by a 10 ml 0.9% saline flush.

Precontrast abdominal CT was first performed, extending from the cranial margin of the diaphragm to the coxofemoral joints. An initial postcontrast series was initiated immediately at the termination of contrast medium injection (arterial phase). A second postcontrast series was initiated at 40 s following initiation of contrast agent administration (portal venous phase). When arterial phase scan time and associated scan delay exceeded 40 s, the portal venous phase was initiated immediately; with a 1-s delay necessary for table movement. A third postcontrast series was obtained 52–120 s following termination of the portal venous phase in 16 cases to evaluate renal excretion. The timing protocol was selected based on results of angiographic CT studies performed in healthy staff-owned dogs of variable breeds and ages. Scan time was calculated in minutes from the initiation of the precontrast series to the termination of the intended portal venous phase.

Transverse CT images (precontrast, arterial, and portal venous phases) were reviewed by the primary author (MMS) and a board-certified radiologist (RTO) on a dedicated DICOM workstation.‡ Reviewers were unaware of patient signalment, date of admission, and sedation status. Images were displayed in a soft-tissue window (with ability to window/level as needed) and a consensus opinion was recorded for the following image quality factors: motion artifact, anatomic exclusion, presence of nonanatomic beam hardening, vascular phase achieved, and presence of contrast agent within the urinary bladder. Objective criteria used for image quality factors are summarized in

TABLE 1. Description of Dogs with Acute Abdominal Signs that were Evaluated Using CE-MDCT Under Minimal Sedation

Breed	Age (years)	Weight (kg)	Mentation	Positioning	Sedation
Norwich Terrier	13.5	6.2	BAR	Sternal	Fentanyl, lidocaine, ketamine CRI 3 mcg/kg/h, 25 mcg/kg/min, 3 mcg/kg/min
Tibetan Spaniel	15.2	6.3	QAR	Dorsal	Butorphanol 0.4 mg/kg
Mix Breed	9.5	29.3	QAR	Dorsal	Butorphanol 0.4 mg/kg, Midazolam 0.2 mg/kg
Labrador Retriever	6	55.5	QAR	Dorsal	Fentanyl 5 mcg/kg, Diazepam 0.2 mg/kg
Mix Breed	7	12.1	QAR	Dorsal	Fentanyl 10 mcg/kg, Midazolam 0.4 mg/kg
Miniature Australian Shepherd	7.7	11	QAR-BAR	Dorsal	Fentanyl 10 mcg/kg, Diazepam 0.2 mg/kg
Bloodhound	4	58	QAR	Sternal	Fentanyl 3 mcg/kg/h
Mix Breed	5.1	28.5	QAR	Dorsal	Fentanyl 5 mcg/kg
Golden Retriever	8	33.9	BAR	Dorsal	Hydromorphone 0.05 mg/kg, Midazolam 0.1 mg/kg
Shetland Sheepdog	10.8	13	QAR	Sternal	Fentanyl CRI 4 mcg/kg/h

CE-MDCT, contrast-enhanced multi-detector computed tomography; CRI, continuous rate infusion; QAR, quiet, alert and responsive; BAR, bright, alert, and responsive.

*GE Lightspeed 16 Slice CT Milwaukee, WI.
†Omnipaque 300™ Iohexol injection, GE Healthcare, Princeton, NJ.
‡PACS workstation Carestream Health, Rochester, NY.

TABLE 2. Criteria Used for Evaluating CE-MDCT Scans in 18 Awake and Sedated Dogs with Acute Abdominal Signs

CT characteristic	Evaluation criteria
Motion artifact	Absent = 0 vs. present (mild = 1: barely noticeable; moderate = 2: noticeable without significant anatomic distortion; severe = 3: easily noticeable, peritoneal organs cannot be evaluated)
Anatomic exclusion	Absent = 0 vs. present (1 = <20% peritoneal cavity; 2 = 20–50% peritoneal cavity; 3 = >50% peritoneal cavity)
Beam hardening	Absent = 0 vs. present (mild = 1: focal to origin however immediately surrounding structures maintain anatomic detail; moderate = 2: signal loss in plane of origin affecting <20% peritoneal cavity; severe = 3: signal loss >20% of surrounding peritoneal contents)
Achievement of arterial phase	0 = No, 1 = Yes
Renal excretion of contrast agent	0 = No, 1 = Yes

Table 2. Vascular phase achieved was based on a selected region of interest (ROI) and Hounsfield unit (HU) measurement within the aorta and portal vein at the level of the porta hepatis; with successful arterial phase imaging defined as an aortic threshold of greater than 250 HU. Overall diagnostic quality was ranked based on a consensus opinion and criteria listed in Table 3.

TABLE 3. Criteria Used for Determining Overall Diagnostic Quality in CE-MDCT Scans of 18 Awake and Sedated Dogs with Acute Abdominal Signs

Diagnostic Quality	Criteria
Excellent = 3	Respiratory/patient motion, beam hardening: Absent or mild (moderate on precontrast only) Anatomic exclusion: Not present Vascular phase achieved: All
Good = 2	Respiratory/patient motion, beam hardening: Moderate-severe/sufficient to hamper regional organ interpretation (in only one phase) or moderate motion in multiple phases. Anatomic exclusion: Graded as 1 on precontrast and/or no more than one postcontrast phase Vascular phase achieved: No more than one (arterial or portal venous) is absent
Fair = 1	Respiratory/patient motion, beam hardening: Moderate-severe/sufficient to hamper regional organ interpretation (affecting two phases; no more than one postcontrast phase) Anatomic exclusion: Graded as 1 on both postcontrast phases Vascular phase achieved: Precontrast and one postcontrast series absent
Poor = 0	Respiratory/patient motion, beam hardening: Moderate-severe/sufficient to hamper regional organ interpretation (in all phases) Anatomic exclusion: Grade of 2 or greater on both postcontrast phases Vascular phase achieved: None of postcontrast series achieved

All statistical tests were selected and performed by the primary author (MMS). A commercial software[§] was used for all statistical analyses and a P-value < 0.05 was considered statistically significant. Continuous data were assessed for normality using a Shapiro-Wilk test on a per group basis (awake vs. sedated).[51] For continuous data that met the assumption of normality, a Levene's test was performed to assess for homogeneity of variance.[52] Following verification of homogeneity of variances, an independent samples t-test was performed to compare the dependent continuous variables in awake vs. sedated patients. For comparison of ordinal data or nonnormally distributed continuous data between groups (sedated vs. awake), the Mann-Whitney U test was used.[53] Mean, minimum-maximum (min-max) and standard deviation (SD) were reported for normally distributed data while median and min-max were reported for nonnormally distributed data. Dependent (continuous and ordinal) variables evaluated were: mentation status, age, weight, duration of clinical signs preceding CT (days), hydration status, degree of abdominal pain, systolic blood pressure (17/18 patients), serum lactate (16/18 cases), serum creatinine (16/18 cases), urine specific gravity (12/18 cases), scan time from first precontrast image to termination of portal venous phase, motion artifact pre and postcontrast, anatomic exclusion pre and postcontrast, measured aortic and portal venous HU measurements during intended phase respectively at the level of the porta hepatis and overall diagnostic quality.

For comparison of categorical variables between groups (sedated vs. nonsedated), a Fisher's exact test was used.[54] Categorical variables included patient sex, surgical vs. medical underlying condition, and achievement of the arterial postcontrast phase. In cases where specific dependent variables failed to show a statistically significant difference between groups, data were pooled for further evaluation.

Results

Eighteen client-owned dogs met the inclusion criteria. Ten dogs underwent contrast-enhanced MDCT evaluation of the abdomen under sedation and eight dogs were scanned awake. Eight of the ten sedated patients had IV sedation at the time of the CT scan and two patients had recent pharmacological intervention that included sedatives (Table 1). Breeds represented in this group included one each of the following: Golden Retriever, Bloodhound, Australian Shepherd, Labrador Retriever, Tibetan Spaniel, Norwich Terrier, and Shetland Sheepdog. Three mixed breed dogs were also included in this group. Six dogs in this group were male (three intact, three neutered) and four were female (all spayed). The mean age was 8.68 years

[§]SPSS IBM Company, Chicago, IL.

(range = 4–15.2 years, SD = 3.6). Median body weight was 20.75 kg (min-max = 6.3–58 kg). Three patients were scanned in sternal recumbency with the aid of the VetMouseTrap™** device (head facing away from the CT gantry) and seven in dorsal recumbency (head facing into the CT gantry). Within the VetMouseTrap™ device, patients were maintained in place with a variable number of foam wedges placed along the lateral chest and abdominal walls and over the neck. Two wide Velcro straps that were fitted to the CT table were then wrapped around the VetMouseTrap™ or patient's dorsum (if the lid was not used). Patients scanned in dorsal recumbency were placed within a cushioned trough fitted with Velcro straps to secure both the forelimbs and hindlimbs individually. Wide Velcro straps were wrapped around the patient and trough for further security.

Eight patients underwent awake abdominal CT. Breeds represented in this group included one each of the following: Scottish Terrier, Basenji, Shih Tzu, Yorkshire Terrier, American Pit Bull Terrier, Boxer, Pug, and Pomeranian. Five were male (one intact, four neutered), and three were female (all spayed). The mean age was 6.79 years (min-max = 4–9.1 years, SD = 1.87). The median weight was 8.4 kg (min-max = 5.3–37.5 kg). Mentation status recorded at the time of imaging was quiet, alert, and responsive in five patients, bright, alert, and responsive in two (American Pit Bull Terrier and Pug) and dull quiet, alert, and responsive in one (Pomeranian). Two patients were scanned in dorsal recumbency within a cushioned trough (American Pit Bull Terrier and Boxer) while the remainder were scanned in sternal recumbency with the aid of the VetMouseTrap™ device (positioned as previously described).

The following continuous dependent variables were normally distributed: age, systolic blood pressure, serum lactate, serum creatinine, and urine specific gravity. Following confirmation of homogeneity of variances, independent samples t-testing revealed that serum creatinine was the only variable for which the null hypothesis was rejected (P-value = 0.041). Mean serum creatinine in the awake group was 0.71 mg/dL, while in the sedated group was 0.99 mg/dL. While a statistically significant difference was detected, these values remain within the acceptable normal canine reference range. All remaining normally distributed dependent variables did not differ between awake and sedated groups.

Total scan time was less in awake vs. sedated groups ($P = 0.055$). Median scan time in the awake group was 6.56 min while in the sedated group was 9.79 min.

For all dependent categorical variables (patient sex, surgical vs. medical treatment, and achievement of the arterial phase), no differences were identified between awake and sedated groups ($P = 1.0$, 1.0, and 0.275, respectively). Based on the lack of statistically significant differences in categorical variables between groups, data for all 18 dogs were pooled for analyses described below.

Duration of clinical signs preceding CT scan showed a median of 5 days (min-max = 1–10 days). Reported clinical signs included, but were not limited to, the following: Vomiting (14 cases), lethargy (5), inappetence (12), and respiratory distress (1). Results of laboratory testing obtained in the same visit revealed a mean lactate 3 (min-max = 0.70–8, SD = 1.98), mean creatinine of 0.87 (min-max = 0.50–1.50, SD = 0.27) and mean urine specific gravity of 1.0309 (min-max = 1.01–1.05, SD of 0.02). No patients were azotemic prior to diagnostic imaging. For the 16 patients, scanned using a delayed venous phase, all scans confirmed renal excretion bilaterally. Mild dehydration was reported in the majority of patients (10) on the basis of physical examination findings. Three patients were considered moderately dehydrated and two severely dehydrated. IV fluid therapy was administered as deemed necessary by the attending clinician either prior to or during CT evaluation. Abdominal pain as assessed by physical examination was reportedly absent (4 cases), mild (8), mild to moderate (1), moderate (4) and moderate to severe (1). Systolic blood pressure (obtained in 17/18 patients) showed a mean of 153.2 mmHg (min-max = 70–200 mm Hg, SD = 30.56). Eight cases would require medical management while ten were considered to suffer from conditions requiring surgical intervention.

Total scan time ranged from 3.47–31.6 min with a median scan time of 7.95 min. Seventeen scans were performed in less than 19 min and 11 scans in less than 10 min. The arterial phase was successfully achieved in 14/18 cases (78%), based on an aortic HU criteria of greater than 250 at the level of the porta hepatis. In the four cases that failed this criterion, aortic HU measurements ranged from 187.6–244. In the portal venous phase, portal vein attenuation values at the level of the porta hepatis ranged from 139.6–280 (median 168.7). A successful portal venous phase was not achieved in one patient due to motion artifact.

Across all scans (precontrast, arterial and initial portal venous phase; $N = 54$), 15/54 (28%) were rated as having no motion artifact, 30/54 (56%) mild motion artifact, 4/54 (7%) moderate motion artifact, and 5/54 (9%) severe motion artifact. The majority of scans were rated as having no beam hardening artifact (48/54, 89%), with mild artifact in 3/54 (5.5%) scans and severe in 3/54 (5.5%). Anatomic exclusion did not occur in the majority of scans 48/54 (89%), with anatomic exclusion of less than 20% of the peritoneal cavity observed in 6/54 (11%) scans. In scans with anatomic exclusion, this was limited to the cranial abdomen and ranged from a single slice of the cranial-most liver to an estimated 2/3 of the liver parenchyma. Overall diagnostic quality (based on criteria summarized in Table 3) was excellent in 9/18 (50%) cases, good in 4/18

**VetMouseTrap™ University of Illinois, Urbana, IL.

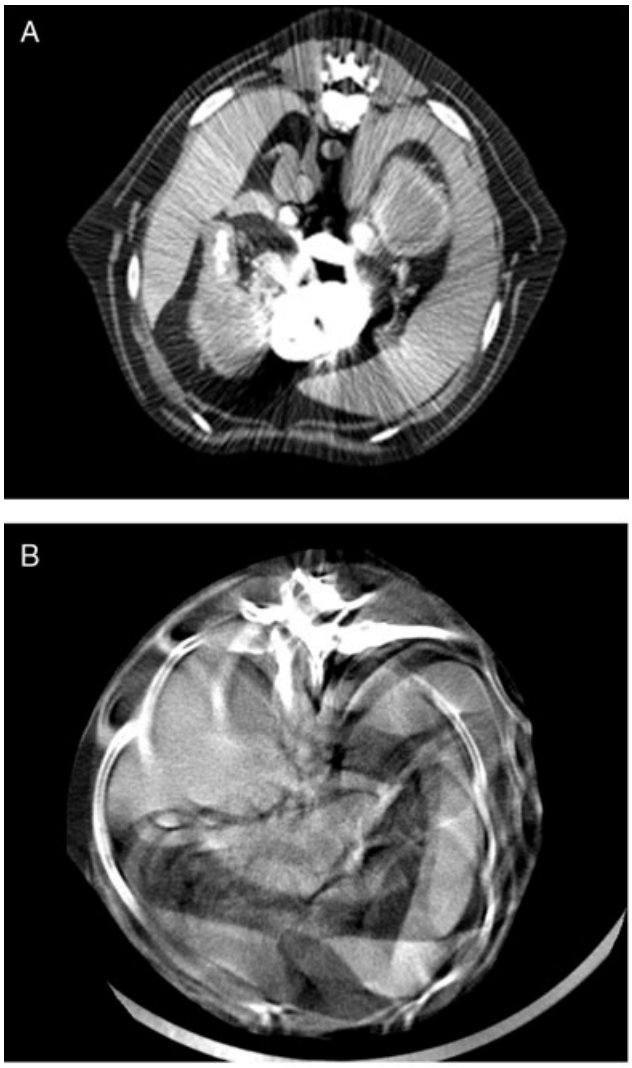

FIG. 1. Transverse contrast-enhanced MDCT image examples of diagnostic studies of poor quality in awake dogs with acute abdominal pain. (A) A 7-year-old male castrated Boxer who underwent awake CT evaluation. Note, severe beam hardening artifact due to barium within the transverse colon (white arrow). (B) A 10.8-year-old male intact Shetland Sheepdog who was recently discontinued from a continuous rate infusion of fentanyl, lidocaine, and ketamine prior to CT evaluation. Note, severe motion artifact with complete distortion of regional visceral anatomy.

(22%), fair in 3/18 (17%), and poor in 2/18 (11%). Of the two poor quality diagnostic scans, one was the result of severe beam hardening secondary to prior GI barium administration (Fig. 1A) and the second was due to failure to capture a true arterial phase (aortic HU 187.6; less than the preassigned aortic threshold) and severe motion artifact in both initial postcontrast scans (Fig. 1B). In the latter case, a delayed venous scan was obtained 52 s following termination of the intended portal venous phase and was characterized by moderate motion in the cranial abdomen and persistent visceral parenchymal enhancement. This scan was considered to be of sufficient diagnostic quality for clinical decision-making when all available images were interpreted. For two of the excellent diagnostic quality scans, sub-millimeter jejunal arteries were visible (Fig. 2).

Discussion

Targeted helical CT protocols for nonlocalizable abdominal pain and for patients with a working clinical diagnosis have been established and are used routinely in the human clinical setting.[2–4] In an attempt to maximize our ability to evaluate a wide spectrum of potential acute abdominal diseases, a dual-phase protocol was adopted (precontrast, arterial and portal venous phases). An optional delayed scan was added to the protocol for some dogs to ensure renal excretion (Table 4). With the exception of two poor diagnostic quality scans, all remaining scans were rated as fair-to-excellent diagnostic quality with no statistically significant difference in diagnostic quality scores between awake and sedated groups.

Image quality was sufficient to permit the creation of maximum intensity projection (MIP) and three-dimensional (3D) volume-rendered (VR) reconstructions of mesenteric arteries for some of the awake and sedated dogs in our study (Fig. 2). This observation warrants further investigation, as evaluation of mesenteric vasculature is an important prognostic indicator in human patients with acute pancreatitis or ischemic bowel disease. In a case series describing the contrast-enhanced CT diagnosis of acute bowel infarction in people, the following findings reportedly demonstrate a specificity of greater than 95%: superior mesenteric artery or vein thrombosis, intramural bowel gas, portal vein gas, focal lack of bowel enhancement, and ischemia of other organs.[55] In one CT study, arterial obstruction resulted in an 89% mortality rate while venous obstruction only resulted in 11%.[56]

No statistically significant differences were identified between awake and sedated groups for signalment, clinical signs, or physical examination findings. There were no statistically significant differences between groups in laboratory parameters with the exception of serum creatinine, although all serum creatinine values were within the normal range in all cases. Behavioral assessment performed on an individual basis at the time of hospital admission and primary clinician preference were the main criteria used for awake vs. sedated group assignments in our dogs.

A statistically significant difference in overall scan time was detected between groups. The sedated group unexpectedly had a median scan time that was greater than in the awake group, with a difference of 3.23 min. We theorize that this small increase in scan time may have been related to the fact that these patients often required additional monitoring between pre and postcontrast phases. Overall, median

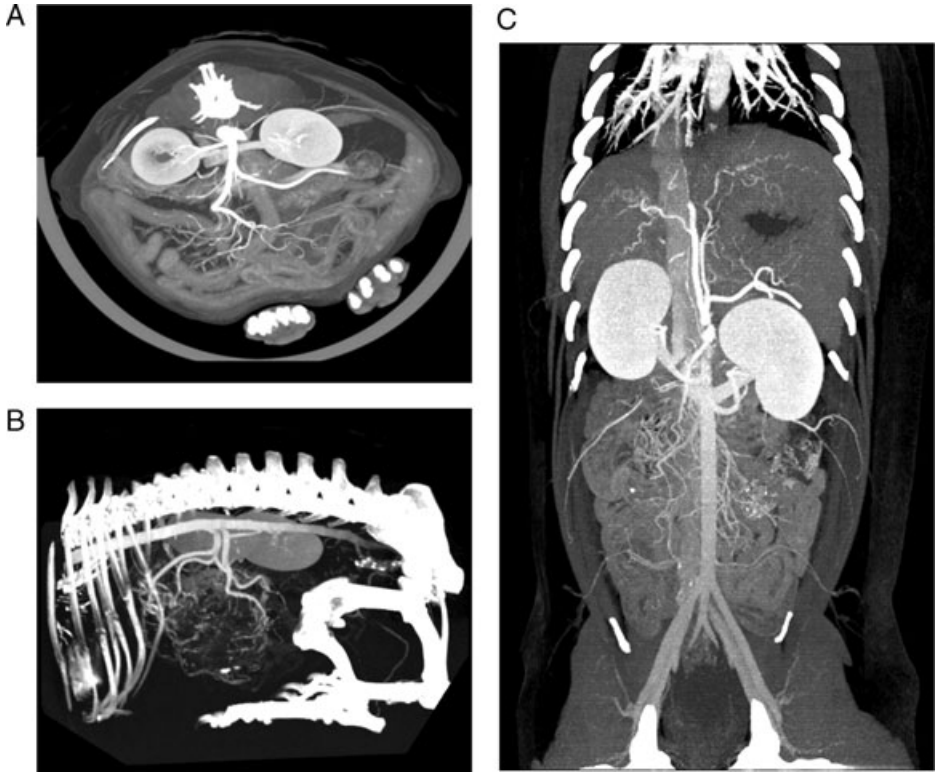

FIG. 2. Maximum intensity projection (MIP) and 3D volume rendering (VR) reconstructions from contrast-enhanced MDCT scans of excellent diagnostic quality obtained in the arterial phase for dogs with acute abdominal pain. (A) A 7-year-old male neutered Scottish Terrier who underwent awake CT. Transverse plane MIP displayed with window width of 800, window level of 70, individual slice thickness of 0.625 mm, and slab thickness of 29.8 mm. The patient's right is to the reader's left. The patient was positioned in sternal recumbency within the Vetmousetrap™ device. (B) A 3D VR reconstruction displayed with window width of 600 and window level of 374 of the same patient as in part (A). The patient's head is oriented to the reader's left. (C) An 8-year-old female spayed mix breed dog who underwent CT with IV sedation (single 5 microgram/kg fentanyl bolus). Dorsal plane MIP displayed with window width of 328, window level of 140, individual slice thickness of 0.625 mm, and slab thickness of 37.5 mm. The patient's right is to the reader's left.

scan time across all patients was rapid and less than 10 min. While scan timing for our study did not include patient positioning, preparation of contrast medium, and scout planning, we would anticipate that these factors should play a minimal role if the imaging staff is well trained and adopts an organized team approach. Scan protocols for our study were preset according to the patient's weight. Use of the power injector in larger patients also permitted consistency in timing of injection and postcontrast scans. However, administration of a flush at the termination of injection likely contributed to failure of arterial capture in at least one of our cases. We therefore would recommend priming an extension set with additional contrast medium and disconnecting the extension set for catheter flushing only at the termination of the exam.

Obtaining a delayed venous scan not only provided additional data in patients that had motion artifacts in the prior scans, but also helped document the absence of acute anuric or oliguric renal failure that could theoretically result from administration of nonionic iodinated contrast material in dehydrated patients. However, we acknowledge that major contrast-related adverse events for dogs receiving nonionic iodinated contrast media have not yet been reported in the veterinary literature and only a limited number of adverse reactions have been reported following administration of ionic contrast media.[57–59] Evaluation of

TABLE 4. Description of Recommended Dual-Phase CE-MDCT Protocol for Awake and Sedated Dogs with Acute Abdominal Signs

Scan field	Arterial phase	Portal venous phase	Delayed phase (optional)
All phases scanned cranial to caudal. Cardiac apex to coxofemoral joints.	Initiate immediately at termination of contrast injection	Initiate at 40 s post start of contrast injection. If arterial scan time + initial scan delay exceeds 40 s, then initiate this phase immediately following arterial phase.	Initiate scan at 120 s following termination of the portal venous phase to confirm renal excretion of contrast.

Patient weight < 20 lbs → 600 mgI/kg rapid hand-injected bolus.
Patient weight > 20 lbs → 600 mgI/kg via power injector at a rate of 3 ml/s
Scan parameters: kV 120; mA 200–325; slice width 2.5 mm with 1.25 mm overlap; pitch 0.9–1.3:1; rotation time 0.5 s

patient laboratory findings (most importantly blood urea nitrogen/creatinine when available) was performed in all our cases prior to diagnostic imaging and IV fluid therapy was recommended as needed. Based on human studies, IV normal saline volume supplementation reduces the risks of contrast-induced nephropathy, is relatively cost-effective, safe, and should be considered in all patients undergoing procedures with intravascular contrast.[60] Using the lowest possible effective dose of contrast media in addition to the potential use of iso-osmolar contrast media in high-risk patients are additional reported recommendations in the human literature.[61] The dose and rate of administration of IV contrast agent in this study was found to be safe and effective. Future studies of the efficacy of lower contrast medium doses may be beneficial; especially for assessing perfusion of the gastrointestinal tract and pancreas that are commonly implicated in canine acute abdominal conditions.

The value of noncontrast enhanced helical CT has also been reported for people with acute abdomen signs. In one study, unenhanced helical CT yielded superior results to a three-view abdominal radiographic series with a sensitivity, specificity, and accuracy of 96%, 95.1%, and 95.6% respectively; compared with radiographic sensitivity, specificity and accuracy of 30%, 87.8% and 56% respectively.[62] A second study evaluating noncontrast-enhanced MDCT identified a sensitivity, specificity, and positive predictive value of 100%, 98.5% and 91.7%, respectively for the detection of free gas, stones, and intestinal obstruction.[63] A third study found no statistically significant difference between unenhanced and contrast-enhanced CT in the ability to diagnose a suspected acute abdominal process.[64]

Primary limitations of our study included small sample size, unequal group numbers, and nonrandomized group assignments. Patient enrollment and client consent were challenging, given that contrast-enhanced MDCT of the acute abdomen is not the current standard of care. It is our hope that results of this study will reduce challenges for future studies and encourage more primary care clinicians to choose MDCT for evaluating their canine patients with acute abdominal conditions.

In conclusion, findings from our study supported the hypothesis that dual-phase contrast-enhanced MDCT protocol is feasible and safe for use in awake or minimally sedated dogs with acute abdominal signs. We also developed and described a standardized protocol for use in future studies. A controlled clinical study comparing this protocol with current standard imaging techniques would be needed in order to determine whether dual-phase MDCT should be the modality of choice for dogs with acute abdominal disease.

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