COMPARISON OF COMPUTED TOMOGRAPHIC ANGIOGRAPHY AND ULTRASONOGRAPHY FOR THE DETECTION AND CHARACTERIZATION OF PORTOSYSTEMIC SHUNTS IN DOGS

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The purpose of this retrospective study was to compare the accuracy of computed tomographic angiography (CTA) and abdominal ultrasonography in detecting and characterizing portosystemic shunts (PSS) in dogs. Medical records of 76 dogs that underwent CTA and/or abdominal ultrasonography suspected to have PSS were reviewed. Presence or absence, and characterization of PSS (when present) on CTA were reviewed by a board-certified veterinary radiologist that was blinded to the clinical findings. The abdominal ultrasonography findings were reviewed from the medical records. Visualization and description of the origin and insertion of PSS on CTA and abdominal ultrasonography were related with laboratory, surgical, or mesenteric portographic confirmation of the presence or absence of PSS. The sensitivity for detection of PSS with CTA (96%) was significantly higher than abdominal ultrasonography (68%; $P < 0.001$). The specificities for CTA and abdominal ultrasonography were 89% and 84%, respectively ($P = 0.727$). Computed tomographic angiography detected the correct origin in 15 of 16 dogs and correct insertion in 15 of 16 dogs with congenital PSS. Abdominal ultrasonography detected the correct origin in 24 of 30 dogs and correct insertion in 20 of 33 dogs with congenital PSS. Multiple acquired PSS were seen in four of five dogs and in one of six dogs on CTA and abdominal ultrasonography, respectively. Computed tomographic angiography was 5.5 times more likely to correctly ascertain the presence or absence of PSS when compared to abdominal ultrasonography ($P = 0.02$). Findings indicated that CTA is a noninvasive diagnostic modality that is superior to abdominal ultrasonography for the detection and characterization of PSS in dogs. © 2013 *Veterinary Radiology & Ultrasound.*

Key words: computed tomography, dog, imaging, portosystemic shunt, ultrasonography.

Introduction

DIAGNOSTIC IMAGING OF THE abdomen is commonly performed in dogs suspected to have portosystemic shunts (PSS). Accurate preoperative diagnosis and characterization of anomalous portal vasculature has a direct impact on the selection of appropriate surgical intervention: dogs without macroscopic PSS or dogs with multiple acquired PSS may not benefit from undergoing laparotomy, whereas the prognosis associated with successful surgical attenuation of single congenital PSS is favorable.[1] As the morphology of PSS can vary tremendously, detailed characterization of vascular anatomy preoperatively facilitates shunt identification during exploratory laparotomy, and potentially reduces both operative time and morbidity associated with the surgery.

Abdominal ultrasonography is a very popular imaging technique used to determine the presence of a PSS, as it is noninvasive, widely available, and does not require general anesthesia. The reported accuracy of detecting the presence or absence of a PSS using this modality is variable however, with sensitivities and specificities ranging from 47–95% and 67–100%, respectively.[2–5] The wide variation in accuracy that is reported between different studies is likely to be a reflection of specific factors associated with abdominal ultrasonography, including high interoperator variability, inconsistent visualization of the aberrant vessels, and advances in equipment imaging quality and technology (such as Doppler abdominal ultrasonography).[3] Abdominal ultrasonography may detect the existence of an anomalous vessel, but the exact origin and insertion of the shunt is not reliably predicted.[3,5]

Computed tomographic angiography (CTA) has recently shown promise for evaluating dogs with suspected PSS.[6–10] Moreover, with the increasing availability of multidetector CT scanners, dual-phase abdominal CTA of high resolution can be readily achieved, resulting in the ability to acquire detailed studies of abdominal vasculature. Such

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studies have the advantage of being obtained in a rapid, noninvasive manner, and can be reformatted to depict vessels in multiple planes, or in three dimensions. Computed tomographic angiography has therefore evolved into the gold standard in assessing the portal vasculature in humans.[11] Preliminary investigations in dogs suggest CTA compares favorably against other methods of PSS diagnostics.[7,10]

The perceived imaging merits of CTA over abdominal ultrasonography for dogs suspected of having PSS has yet to be demonstrated within a single investigation. The purposes of this study were to (1) compare the accuracy of CTA to abdominal ultrasonography in diagnosing the presence or absence of PSS, and (2) compare the accuracy of CTA to abdominal ultrasonography in characterizing PSS morphology in dogs. We hypothesized that CTA is superior to abdominal ultrasonography for the detection of PSS, and also provides better characterization of shunt morphology.

Materials and Methods

The medical records of dogs with a clinical history or laboratory findings suggestive of a PSS examined at the University of Florida Veterinary Medical Center between January 2007 and October 2009 were reviewed retrospectively. Only dogs that underwent CTA and/or abdominal ultrasonography with confirmed presence or absence, and confirmed morphology of a PSS (when present) were included in the study. Dogs were excluded from the study if the true insertion of the PSS to the systemic venous system was not recorded or identified during mesenteric portography and/or exploratory laparotomy. Confirmation of the presence of any PSS and determination of shunt morphology were made based on mesenteric portography and/or exploratory laparotomy. The absence of PSS was confirmed by negative colonic scintigraphy, negative mesenteric portography, negative exploratory laparotomy, and/or normal pre- and postprandial bile acids. Dogs with normal bile acids did not undergo CTA, nuclear scintigraphy, or exploratory laparotomy. Shunt morphology was characterized in the medical records as congenital intrahepatic (left, right, central divisional), congenital extrahepatic (portal/gastroduodenal/left gastric/splenic/cranial mesenteric/caudal mesenteric, to caval/renal/azygous/iliac), or acquired extrahepatic. For the data analysis and comparisons, extrahepatic shunts noted as arising from the portal, left gastric, or splenic veins were classified to be arising from the splenic vein; gastroduodenal shunts were classified to be arising from the right gastric vein.[10] Shunt morphology was characterized as acquired extrahepatic PSS if intraabdominal varices were identified on abdominal ultrasonography or CTA; however, acquired PSS were not further subclassified according to recently described morphologies.[12]

Abdominal Ultrasound

All abdominal ultrasonography were performed by board-certified veterinary radiologists. Dogs were imaged in dorsal recumbency with or without sedation with the same ultrasound equipment (Philips iU22, microconvex C8–5, convex C9–4, and microlinear L15–7io transducers, Philips Healthcare, Andover, MA). Color-flow Doppler was used to assist with identification of PSS in all abdominal ultrasonography cases. Subjective assessment of liver size, hepatic portal vasculature, portal vein/aorta ratio, portal vein/caudal vena cava ratio, renomegaly, and urolithiasis were variably reported in the medical records; these data were not analyzed in the study. Detection of a PSS on abdominal ultrasonography was only recorded as present if the origin and/or insertion of the suspect PSS was observed. Abdominal ultrasonography findings were recorded as absent PSS if an aberrant vessel was not observed. The origin and/or insertion of the PSS on abdominal ultrasonography as documented in the medical records were compared to the surgical/portogram findings.

Computed Tomographic Angiography

Dogs were imaged with an 8-slice helical CT scanner (Toshiba Aquilon 8 CT Scanner, Toshiba Medical Systems, Tustin, CA) using a pitch of 1. All images were acquired with dogs under general anesthesia in dorsal recumbency. Approximately 20 seconds of manual hyperventilation, an intravenous bolus of fentanyl or remifentanil, and/or manual breath-hold was used to induce transient apnea.

For the CTA studies, iodinated contrast medium (Omnipaque 350, GE Healthcare, Milwaukee, WI) at the dosage of 640 mgI/kg was injected in a single bolus at a rate of 3 ml/s via a power injector into the left or right cephalic vein. The CTA protocol consisted of acquiring a precontrast-enhanced volume of the caudal thorax and abdomen, and three postcontrast volume acquisitions, named as arterial, venous, and delayed phases, performed using the bolus triggering technique, as previously described,[8] using a proprietary bolus tracking software (SureStart, Toshiba Medical Systems, Tustin, CA) to obtain peak contrast enhancement in the selected region-of-interest. This resulted in a broad variation of scan delay (from 10 to 50 s) between the postcontrast sequences, taking into consideration the different sizes of the dogs imaged. Due to the same reason, slice thickness (ranging from 1 to 4 mm), slice interval (ranging from 1 to 3 mm), reconstruction interval (ranging from 1.0 to 2.5 mm), and KVp (around 120 KVp) and mAs (ranging from 128 to 400 mAs) settings were adjusted accordingly, for each individual dog size.

A DICOM workstation (Kodak DirectView web software, Eastman Kodak Company, Rochester, NY) was used to generate 2D multiplanar reformation images and 3D images of the portal system from the portal phase scan. Transverse, dorsal, and sagittal plane images were used to assess portal vasculature. For the purposes of this study, all CTA images were reassessed by one board-certified veterinary radiologist (S.L.R.) that was blinded to the clinical findings of the cases. Detection of PSS was recorded as present on CTA when the origin and insertion of an aberrant portal vessel was identified and reported by the blinded radiologist. Absence of PSS on CTA was recorded when a shunt vessel was not visualized. The origin and insertion of the PSS on CTA as documented by the blinded radiologist were compared to surgical/portogram findings.

Data Analysis

Dogs undergoing abdominal ultrasonography or CTA were analyzed as two independent groups. The sensitivity and specificity of both imaging modalities for identifying the presence or absence of PSS was calculated. Sensitivity and specificity of determining the presence or absence of PSS was compared between CTA and abdominal ultrasonography using a difference in two proportional means test. If a PSS was seen on abdominal ultrasonography or CT with an incorrect/unidentified origin or insertion, and the dog had a PSS on surgery or portography, the case was deemed to have been positively identified (but not correctly characterized). Odds ratios for correct PSS identification between CTA and abdominal ultrasonography was also calculated. The proportion of correct identification of the origin and insertion for each imaging modality was calculated. Cases were excluded from the analysis of shunt characterization if the origin was not identified on portography or surgery. Identification of the origin or insertion of the shunt was considered incorrect if the origin or insertion was not seen on abdominal ultrasonography or CT, but seen on portography or surgery. For all comparisons, a $P < 0.05$ was considered significant. All statistical analyses were performed by the primary author (S.K).

FIG. 1. Transverse plane portal phase CTA of a 2 kg, 1-year-old Chihuahua suspected to have PSS. A small communication between the caudal vena cava (black arrow) and the left gastric vein (white arrow) was suspected. The portal vein (open arrow) was noted to arborize into the liver normally. No PSS was identified on abdominal exploratory laparotomy. Note the poor image resolution due to the small size of the dog.

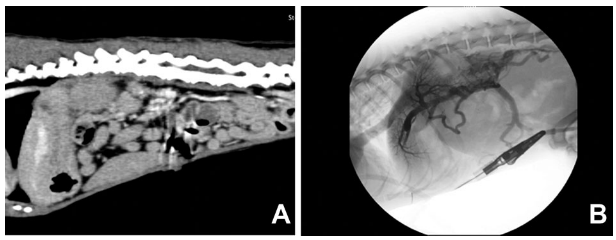

FIG. 2. Sagittal plane reconstructed portal phase CTA (A) and mesenteric portogram (B) of a 2 kg, 3-year-old Yorkshire terrier with multiple acquired extrahepatic PSS. The abnormal network of vessels is visible on both modalities; however, the vessels were not specifically identified as multiple acquired PSS on the CTA. Note the poor image resolution due to the small size of the dog.

Results

Seventy-six cases met the inclusion criteria. Twenty-four dogs were imaged with both abdominal ultrasonography and CTA, seven dogs underwent CTA only, and 45 dogs had an ultrasound only. In cases that had both abdominal ultrasonography and CTA, abdominal ultrasonography was always performed before CTA. The mean age was 2.1 years (range 3 months–9 years). The most frequently represented breeds included Yorkshire Terriers (22), Chihuahuas (6), Maltese Terriers (5), and Miniature Schnauzers (4). There were four medium-to-large size dogs, two of which were Golden Retrievers. Presence of PSS was confirmed in 57 dogs by exploratory laparotomy (49) or operative mesenteric portography (8), and the absence of PSS was confirmed in 19 dogs by negative colonic scintigraphy (2), negative mesenteric portography (3), negative exploratory laparotomy (7), or normal pre- and postprandial bile acids (7).

Of 22 dogs with PSS definitively confirmed that underwent preoperative CTA, PSS was identified on CTA in 21 dogs. Of nine dogs without PSS that underwent CTA, absence of PSS was correctly diagnosed in eight dogs. That is, there was one false positive and one false negative result with CTA: a splenic to caudal vena cava PSS was suspected in Chihuahua with no PSS identified on exploratory laparotomy (Fig. 1), and no PSS was reported on CTA in a dog with multiple acquired PSS seen on mesenteric portography (Fig. 2). Of 50 dogs with PSS definitively confirmed that underwent preoperative abdominal ultrasonography,

TABLE 1. Sensitivities and Specificities for Computed Tomographic Angiography and Abdominal Ultrasound for Detection of Portosystemic Shunts

	Computed tomographic angiography	Abdominal ultrasonography	P-value*
Sensitivity (%)	96 [75.1–99.7†]	68 [54.2–79.2]	<0.001
Specificity (%)	89 [50.7–99.4]	84 [62.4–94.5]	0.727

*P-value represents the comparison of sensitivity or specificity between computed tomographic angiography and abdominal ultrasonography.
†95% confidence intervals for sensitivity and specificity.

PSS was identified on abdominal ultrasonography in 34 dogs. Of 19 dogs without PSS that underwent abdominal ultrasonography, absence of PSS was correctly diagnosed in 16 dogs (i.e., there were three false positive and 16 false negative results with abdominal ultrasonography).

The sensitivity and specificity of CTA and abdominal ultrasonography for correctly identifying the presence or absence of PSS are listed in Table 1. There was a significant difference in the sensitivity of detecting the presence of PSS between the two imaging modalities ($P < 0.001$); no significant difference was observed in specificity between the two imaging modalities ($P = 0.727$). Computed tomographic angiography was 5.5 times more likely to correctly ascertain the presence or absence of PSS when compared to abdominal ultrasonography ($P = 0.02$).

Portosystemic shunts morphology, confirmed on exploratory laparotomy or mesenteric portography, varied widely. Six dogs had intrahepatic PSS (five left divisional, one right divisional); eight dogs had multiple acquired PSS; the remaining 43 dogs had congenital extrahepatic PSS (varying origin-insertion combinations of: 42 with splenic vein origin, and two with left colic vein origin; 23 with caval insertion, 19 with azygous insertion, and two with left renal vein insertion). One mix-breed dog had two congenital extrahepatic PSS. In this dog, a single spleno-azygous PSS was seen on abdominal ultrasonography, whereas a splenorenal PSS as well as the spleno-azygous PSS was identified on both preoperative CTA and during exploratory laparotomy. Multiple acquired PSS were seen in one of six dogs and in four of five dogs on abdominal ultrasonography and CTA, respectively.

In dogs where a congenital PSS was identified on CTA and surgery or portography, the correct origin was reported on CTA in 15 of 16 dogs; the origin was not reported in one dog. Similarly the correct insertion was reported on CTA in 15 of 16 dogs; in one dog, the insertion was classified as the external iliac vein, whereas the insertion was definitively identified as the caudal vena cava on exploratory laparotomy. In dogs where a congenital PSS was identified on abdominal ultrasonography, and the origin defined by surgery or portography, this origin was reported correctly on abdominal ultrasonography in 24 of 30 dogs; the origin was not determined in six dogs. In dogs where a congenital PSS was identified on abdominal ultrasonography, and the insertion defined by surgery or portography, the correct insertion was reported on abdominal ultrasonography in 20 of 33 dogs; the insertion was not determined in four dogs, and the insertion was incorrectly identified in nine dogs.

Discussion

The results of this study corroborate that CTA is a highly accurate diagnostic modality for detecting the presence and characterizing the anatomy of PSS in dogs. Consistent with previous studies,[6–8,10] we demonstrated CTA provides excellent anatomic characterization of anomalous intraabdominal vasculature, with CTA and surgical findings matching in 94% of cases. Whereas abdominal ultrasonography was a highly specific test when PSS was seen, this modality was less sensitive and had a poorer ability to correctly detail shunt morphology when compared to CTA.

These findings, which illustrate the superiority of CTA over abdominal ultrasonography for detecting PSS, are not surprising. The modest sensitivity of 68% in our study reflects the difficult nature of visualizing PSS with abdominal ultrasonography.[3–5] The diagnostic accuracy of abdominal ultrasonography is also highly dependent on operator skill and experience, and abdominal ultrasonography in this retrospective analysis were not all performed by a single radiologist. In contrast, CTA consistently provided high resolution, multiplanar cross-sectional images. The captured cross-sectional CTA slices and three-dimensional reconstructions of the entire abdomen could be reviewed more patiently and systematically than the real-time images being acquired from a dog undergoing abdominal ultrasonography. Computed tomographic angiography had the added benefit of the ability to trace vasculature outside the abdomen. This was particularly advantageous in cases with azygous PSS that inserted into the systemic venous circulation within the thorax.

Computed tomographic angiography appears to be the imaging modality of choice with respect to preoperative planning for dogs undergoing laparotomy for PSS attenuation. Surgical intervention for congenital PSS required placement of the attenuating device as close to the insertion of the shunt as possible. When PSS was identified on abdominal ultrasonography, the origin and insertion of the vessel was correctly described in 80% and 60% of cases, respectively. Computed tomographic angiography, on the other hand, correctly identified the origin and insertion of the anomalous vessel in 94% of cases as determined by surgery or portovenography. We observed that consistent scan planes and orientations allow nonradiologists (i.e., surgeons) to gain a detailed understanding of the course of the vessel within the abdomen prior to surgery. In our hospital, CTA particularly appeared to enhance the degree of confidence in locating and recognizing a PSS intraoperatively for surgeons-in-training or with surgeons with limited experience. In contrast, a surgeon's understanding of PSS typically relied on a verbal description from the radiologist, rather than viewing the images, when an abdominal ultrasonography was performed. Although we were not able to report a comparison of surgical time, additional studies are required to determine whether the knowledge of PSS anatomy obtained with CTA has the potential to help decrease operative time and morbidity.

Conclusive identification of multiple acquired PSS with noninvasive imaging techniques can directly influence subsequent treatment or diagnostic options. Specifically, surgical management of acquired PSS is unrewarding;[13] thus if this condition can be recognized preoperatively, the morbidity associated with a full exploratory laparotomy may be avoided. In this study, these types of vessels were seen on abdominal ultrasonography in only one of six dogs, whereas CTA revealed multiple acquired PSS on four of five dogs. In the one case where multiple acquired PSS was not noted in the CTA, a tortuous network of vessels in the region of the kidney was identified upon rereviewing the images. The apparent superiority of CTA for detecting acquired PSS has also been suggested by previous investigations.[8,12] Based on these findings, dogs suspected to have multiple acquired PSS may benefit from CTA prior to planned surgical exploration.

Despite the apparent advantages of CTA over abdominal ultrasonography, routine use of CTA may not be justified or become widely adopted. Computed tomographic angiography has the major disadvantage of requiring general anesthesia. Computed tomographic angiography imaging is more expensive than abdominal ultrasonography, and high quality studies with appropriate timing are best achieved with newer multidetector scanners.[8,14] The ability to discriminate between two small adjacent vessels can be difficult, especially in smaller sized dogs.[7] Indeed, the one false-positive case on CTA in our series was in a 2 kg Chihuahua. For these reasons, it is unlikely that CTA will replace abdominal ultrasonography as the most common imaging modality in dogs suspected to have PSS.

While a specific shunting vessel may not be visualized, other evidence for PSS such as portal vein size and ratios, hepatic portal markings, microhepatica, and urolithiasis are important for raising the index of suspicion of PSS with abdominal ultrasonography.[5] In this study, we did not attempt to determine whether certain individual ultrasonographic findings, or combination of findings, were diagnostic for PSS. If cases that were "highly suspected" of having a PSS based on indirect evidence on abdominal ultrasonography were classified test positive, the sensitivity of abdominal ultrasonography for PSS detection would have been higher than reported here. Considering that a diagnosis of PSS, acquired or nonacquired, can be suspected with a comparable degree of accuracy using laboratory data,[15] characterization of the abnormal vessels then becomes arguably the most important reason for performing abdominal imaging in these dogs. Thus, our investigation focused on the ability of CTA and abdominal ultrasonography to directly visualize and describe the specific pattern of shunting.

It appeared that shunt nomenclature for the anatomy of PSS in the medical records, including CTA, abdominal ultrasonography, portography, and surgical descriptions, was based on previously reported terminology.[16] One recent study utilizing CTA characterized common patterns of extrahepatic shunting with a high level of detail.[10] In agreement with that investigation, the review of CTA images demonstrated that all extrahepatic PSS originating cranial to the junction of the caudal and cranial mesenteric veins arose from the either the splenic or gastroduodenal/right gastric veins. Based on the controversial nature of naming conventions for extrahepatic PSS, we chose to simplify the description of the origins according to the most recent consensus.[10]

While we were able to identify a clear difference between the accuracies of CTA and abdominal ultrasonography, our results should be interpreted with caution. Because of the retrospective nature of the study, surgeons and radiologists were not blinded to each other's interpretation, which was a major limitation to using the data from medical records. In an attempt to circumvent this bias, we used the findings from a radiologist that was blinded to the clinical findings of all the cases. Given the importance of real-time interpretation for abdominal ultrasonography, we were not able to perform a similar blinded analysis of the abdominal ultrasonography images. For statistical comparisons, CTA and abdominal ultrasonography were analyzed as independent groups; however, dependence of observations within subject may have occurred due to the overlap of those cases receiving both CTA and abdominal ultrasonography. There was also likely an inherent bias in patient selection, as a high proportion of dogs that underwent CTA had shunt morphologies that were difficult to identify with abdominal ultrasonography. While more unusual PSS morphologies may have been overrepresented in the CTA group, all cases that underwent abdominal ultrasonography were consecutively included and likely to be representative of the population of dogs suspected of having PSS at our hospital. Furthermore, it is unlikely that a PSS easily identifiable on abdominal ultrasonography would be any more or less accurately identifiable on CT.

Summarily, CTA was superior to abdominal ultrasonography for the detection and characterization of PSS in dogs. Case-controlled, blinded, prospective studies are warranted to further define the accuracy of CTA and abdominal ultrasonography. However, based on the findings of this study, CTA is a useful modality for precisely defining PSS morphology, particularly in those cases where abdominal ultrasonography does not yield clear results.

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