CONTRAST-ENHANCED MAGNETIC RESONANCE ANGIOGRAPHY FOR DIAGNOSIS OF PORTOSYSTEMIC SHUNTS IN 10 DOGS

Andreas Bruehschwein, Isa Foltin, Katharina Flatz, Martin Zoellner, Ulrike Matis

Computed tomography angiography, sonography, scintigraphy, and portography can be used to evaluate the portal vasculature to evaluate for a portosystemic shunt (PSS). Time-of-flight magnetic resonance angiography (TOF-MRA) and contrast-enhanced MRA (CE-MRA) are other potentially useful techniques. The aim of this study was to evaluate CE-MRA in 10 dogs suspected of having a PSS. Noncontrast MR images of the abdomen were obtained using a Siemens Symphony MR-scanner (1.5 T) and a T1-weighted FLASH-3D sequence with a very short scan time (about 20 s). After injection of contrast medium, the initial sequence was repeated five times. The sequence with the best contrast medium filling of the portal vasculature was selected subjectively, subtracted from the initial survey image series, and a maximum intensity projection (MIP) of the subtraction data, in multiple views, was created. The cross-sectional and MIP images were evaluated for abnormal portosystemic vasculature. A single PSS was identified and confirmed at surgery in all dogs. A portocaval shunt was found in five dogs, a portophrenic shunt in three dogs, a portoazygos shunt in one, and a central divisional intrahepatic shunt in one other dog. Based on our results, CE-MRA is a useful tool for imaging abdominal and portal vasculature and for the diagnosis of a PSS. © 2010 Veterinary Radiology & Ultrasound, Vol. 51, No. 2, 2010, pp 116–121.

Key words: contrast-enhanced MRA, dog, gadolinium, magnetic resonance angiography, magnetic resonance imaging, MRA, portosystemic shunt.

Introduction

Anomalies of the portal vasculature are common in dogs.1–6 Radiographic angiography,1–3,7–9 scintigraphy,8–13 sonography,7,9,14–19 computed tomography angiography,20–23 and magnetic resonance angiography (MRA)24,25 have been used to characterize portosystemic shunts (PSS) in dogs. Time-of-flight (TOF)-MRA, phase-contrast (PC)-MRA, and contrast-enhanced (CE)-MRA are other techniques used for this purpose in humans26 and have been modified for use in dogs.24–31

In dogs, TOF-MRA has been used for the diagnosis of PSS24 and CE-MRA has been used to visualize abdominal and thoracic vasculature, including the cardiac chambers and vessels in the extremities.25–28,30 The test-bolus method, care-bolus method, and serial-measurement method are used for optimal timing of contrast medium application and image acquisition and are applicable to veterinary medicine.26 In a recent study, serial CE-MRA, also called multiphase time-resolved CE-MRA,25 was used to visualize the portal and hepatic vasculature. The aim of the present study was to evaluate multiphase time-resolved CE-MRA for the diagnosis of PSS in dogs.

Materials and Methods

CE-MRA was performed in 10 dogs suspected of having a PSS. Breeds included Jack Russell Terrier (n = 4), Miniature Pinscher (n = 2), Pug (n = 1), Yorkshire Terrier (n = 1), Bavarian Mountain Scent-hound (n = 1) and Golden Retriever (n = 1; Table 1). There were six male and four female dogs, which ranged in age from 3 months to 4 years and weighed 3.0–16.2 kg.

MR imaging was conducted with a 1.5 T MR scanner,* 52 mT/m maximal effective gradient strength, 240 μs minimal effective rise time and 216 T/m/s maximal effective slew rate. A circular polarized spine array coil in combination with a circular-polarized body array flex coil was used. After localizer images (T1-weighted FLASH 2D [fast low angle shot two dimensional], field-of-view [FOV] 500 mm, FOV phase 80%, TR 12 ms, TE 4.8 ms, slice thickness 10 mm) acquired in sagittal, dorsal, and transverse planes, a T1-weighted FLASH-3D sequence was used in the dorsal plane with a matrix of 384 and a single acquisition. The scan parameters varied slightly depending on the size of the patient: FOV size ranged from 300 to

* Magnetom Symphony, Siemens, Healthcare, Erlangen, Germany.
from 72 to 128, voxel size from 1.1 to 1.54 ms, TR from 3.21 to 3.77 ms, flip angle from 25° to 30°, slice thickness from 0.8 to 1.4 mm, number of slices from 72 to 128, voxel size from 1.1×0.8×0.8 mm to 1.7×1.0×1.4 mm and scan time from 19 to 23 s.

The dogs were sedated with diazepam, and anesthesia was induced with propofol. After endotracheal intubation, anesthesia was maintained with isoflurane and oxygen, and the dogs were ventilated mechanically. For MRA, the serial (multiphase time-resolved) measurement technique was used. After a short period of hyperventilation, mechanical ventilation was interrupted and an initial survey scan was carried out during a period of apnea. Mechanical ventilation was resumed once the survey scan was completed. A bolus of 0.5 ml/kg BW (0.25 mmol/kg BW) gadodiamide (Omniscan<sup>®</sup>) was injected rapidly via an IV catheter of 0.6/0.9, 0.8/1.1, or 1.0/1.3 mm [inner/outer diameter] depending on the size of the dog) into the cephalic vein followed by 10 ml of saline solution using a preloaded extension set. Mechanical ventilation was interrupted, and the initial sequence was repeated a minimum of three times immediately after injection of the contrast medium. After three postcontrast acquisitions, which collectively corresponded to approximately one minute of scan time, mechanical ventilation was resumed or dogs started breathing spontaneously. The sequence with the best contrast medium filling of the portal vasculature was selected subjectively, and subtracted from the initial survey image series mask. A maximum intensity projection (MIP) of the subtraction data in multiple views was carried out using the MR scanner software. Additional postprocessing using a mathematic noise suppression algorithm was done. The primary dorsal images, and sagittal and transverse multiplanar reconstructions (MPR), and MIP in a 360° rotation along the longitudinal axis of the body, were evaluated. This was achieved with a soft copy reading environment using MR scanner software and dedicated workstations. The images were reviewed by a board-certified surgeon (U.M.) and an ECVDI radiology resident (A.B.) or veterinarians experienced in reading MR imaging studies (I.F, K.F, M.Z.) in a group of two reviewers (one radiologist and one surgeon). The final imaging diagnosis was reached by consensus opinion. The shunts were named according to published terminology.

After MRA, all dogs underwent abdominal laparotomy for correction of the PSS by an ECVS board-certified surgeon.

### Results

MR data acquisition time was <2 min. Examination time including hyperventilation and contrast medium application was <10 min. An additional 5–10 min were necessary for postprocessing. The postcontrast medium scan with the best contrast medium filling of the portal vasculature occurred within the first two sequences after contrast medium injection in all dogs. The first three acquisitions during the period of apnea were of diagnostic quality in all patients. Further acquisitions contained motion artifacts because of spontaneous breathing or mechanical ventilation, and were not diagnostic. In all dogs, a single abnormal vessel that connected the caudal vena cava or theazygos vein with the portal vein or one of its tributaries was identified, and the origin and termination of the shunts were determined in all dogs.

All dogs underwent surgical correction of the PSS. The MR angiograms were used to guide the surgeon in identifying and occluding the abnormal vessel with an ameroid constrictor. A portocaval shunt was found in five dogs, a portophrenic shunt in three, a portoazygos shunt in one, and one dog had a central divisional intrahepatic shunt (Table 1). The portocaval shunts (Table 1) were large constricted vessels located caudal to the liver and cranial to the kidneys, and connected the caudal vena cava with the portal vein (Fig. 1). The two miniature pinchers (Table 1, dogs 7 and 8) were littermates and each had a portophrenic

Table 1. Patient Data and Shunt Type

<table>
<thead>
<tr>
<th>Dog</th>
<th>Breed</th>
<th>Age</th>
<th>Weight (kg)</th>
<th>Gender</th>
<th>Shunt Location</th>
<th>Shunt Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pug</td>
<td>3 months</td>
<td>3.0</td>
<td>Male</td>
<td>Extrahepatic</td>
<td>Portocaval</td>
</tr>
<tr>
<td>2</td>
<td>Yorkshire Terrier</td>
<td>4 years</td>
<td>3.5</td>
<td>Female</td>
<td>Extrahepatic</td>
<td>Portocaval</td>
</tr>
<tr>
<td>3</td>
<td>Jack Russell Terrier</td>
<td>5 months</td>
<td>4.1</td>
<td>Male</td>
<td>Extrahepatic</td>
<td>Portocaval</td>
</tr>
<tr>
<td>4</td>
<td>Jack Russell Terrier</td>
<td>5 months</td>
<td>3.6</td>
<td>Male</td>
<td>Extrahepatic</td>
<td>Portocaval</td>
</tr>
<tr>
<td>5</td>
<td>Jack Russell Terrier</td>
<td>10 months</td>
<td>7.1</td>
<td>Female</td>
<td>Extrahepatic</td>
<td>Portocaval</td>
</tr>
<tr>
<td>6</td>
<td>Jack Russell Terrier</td>
<td>1 year</td>
<td>8.0</td>
<td>Male</td>
<td>Extrahepatic</td>
<td>Portophrenic</td>
</tr>
<tr>
<td>7</td>
<td>Miniature Pinscher</td>
<td>3 years</td>
<td>4.7</td>
<td>Female</td>
<td>Extrahepatic</td>
<td>Portophrenic</td>
</tr>
<tr>
<td>8</td>
<td>Miniature Pinscher</td>
<td>3 years</td>
<td>6.8</td>
<td>Male</td>
<td>Extrahepatic</td>
<td>Portophrenic</td>
</tr>
<tr>
<td>9</td>
<td>Bavarian Mountain Scenthound</td>
<td>3 years</td>
<td>16.2</td>
<td>Female</td>
<td>Extrahepatic</td>
<td>Portoozygos</td>
</tr>
<tr>
<td>10</td>
<td>Golden Retriever</td>
<td>5 months</td>
<td>15.0</td>
<td>Male</td>
<td>Intrahepatic</td>
<td>Central divisional</td>
</tr>
</tbody>
</table>

1. Fabius Tiro<sup>®</sup>, Draeger, Luebeck, Germany.
2. GE Healthcare Buchler GmbH & Co. KG, Braunschweig, Germany.
3. Braun Mslenung AG, Mslenung, Germany.
5. Contex vision filter (medium setting), Siemens Healthcare.
7. Syngo imaging XS<sup>®</sup>, Siemens Healthcare.
shunt, with almost identical angiograms. The shunt was a long arcuated vessel dorsal to the liver on the left side that connected the caudal vena cava cranial to the liver with the portal vein caudal to the liver (Fig. 2). In the third patient with a portophrenic shunt (Table 1, dog 6), the abnormal vessel also crossed the liver dorsally on the left side and entered the caudal vena cava from the left side cranial to the liver in the immediate vicinity of the diaphragm (Fig. 3). In the dog with the portoazygos shunt (Table 1, dog 9), an enlarged azygos vein, similar in size to the aorta, was detected dorsally in the right thorax. The portoazygos shunt had a straight course and was connected to the portal vein caudally (Fig. 4). The intrahepatic shunt (Table 1, dog 10) connected the portal vein to the caudal vena cava in the hilar region of the liver. The shunt originated cranial to the gastroduodenal vein in the hepatic parenchyma and had a straight course with a wide window to the caudal vena cava. A branch of the portal vein was seen on the left and a faint branch was seen dorsolaterally on the right of the shunt. Because of its location and course it was classified as a central divisional intrahepatic shunt (Fig. 5).

Additional portography (lateral and VD) was carried out during surgery in one dog (Table 1, dog 6). The morphology of the shunt on mesenteric portography closely resembled that described on MRA-MIP (Fig. 3).

Compared with the other angiograms, the quality of images obtained in the dog with the intrahepatic shunt was poor (Fig. 5). Reduced vascular definition of the portal
phase with superimposition of other contrast medium-filled structures and vessels were caused by problems encountered during contrast medium application. There was a short interruption of the manual injection, which created a split bolus and an overlay of different phases. However, the results were still of diagnostic quality.

Discussion

Based on our results, CE-MRA is a suitable noninvasive preoperative diagnostic procedure for assessment of a potential PSS. CE-MRA requires less time (<10 min) than TOF-MRA (40–60 min)\textsuperscript{24} and depicts the abdominal and thoracic vasculature and provides three-dimensional anatomic detail of the portal vein and its tributaries.\textsuperscript{25,26} Serial CE-MRA measurements were easy to carry out, because complex timing as well as knowledge or determination of circulation times using bolus tracking were not necessary. Despite the serial measurement technique with arterial, portal, and venous phases, the MR angiograms are static images.

To avoid motion artifacts, a breath-holding or gated technique appears to be necessary. In the present study, motion artifacts caused by breathing during the fourth or fifth acquisition resulted in nondiagnostic images, which could not be used for subtraction- and MIP-post-processing. Induction of apnea using cisatracurium has been described.\textsuperscript{25} In our patients, hyperventilation before the scan and interruption of mechanical ventilation effectively allowed a 1-min period of apnea in which three good quality postcontrast scans could be obtained. Drug-induced apnea was not necessary in our setting. We used a contrast medium concentration of 0.25 mmol/kg BW, which is similar to other reports,\textsuperscript{25} and therefore we expected comparable vessel contrast and image quality. Larger differences in contrast medium concentration likely affect image quality.
We injected the contrast medium manually at an injection rate of about 3 ml/s. The manual injection rate is imprecise and may cause fluctuation leading to variations in image quality, which probably occurred in dog 10 with the intrahepatic shunt. CE-MRA appears to produce better images than those obtained by TOF-MRA 10 years ago.24,25 However, a meaningful comparison of image quality between TOF- and CE-MRA should be based on comparable up-to-date technologies. On the other hand, TOF-MRA does not require contrast medium, which is expensive and may be associated with side-effects.26 Furthermore, the diagnostic sensitivity and specificity have been determined for TOF-MRA,24 but not for CE-MRA. In our study, it was a coincidence that only dogs with a single congenital PSS were evaluated. Single congenital shunts are often large and easy to detect. The small size of multiple acquired shunts might limit their identification. Thus, the role of equipment and resolution as well as the diagnostic value of CE-MRA for multiple acquired shunts requires further investigation.

Compared with selective mesenteric portography, CE-MRA is nonselective. Therefore, in addition to portal vessels, other abdominal arteries and veins are visible, which makes interpretation more difficult. TOF-MRA can be used for selective abdominal venograms to detect caudocranial (presumed venous) flow and suppress craniocaudal (presumed arterial) flow. However, vessels with in-plane flow and tortuous vessels can create complex flow phenomena and flow voids, which may complicate interpretation.26 Nonselective MR angiograms, with visualization of all abdominal vessels during the portal phase, may be confusing and cause orientation problems. This is especially true when the reader is accustomed to selective mesenteric portovenograms or is not familiar with vascular anatomy. These problems can be overcome by using the anatomic information from the primary cross-sectional images in combination with the portal-phase and arterial-phase MIP images. Identification of the aorta, caudal vena cava and portal vein should precede the search for abnormal connections between the portal vein or one of its tributaries and the caudal vena cava or theazygos vein. In the present study, all shunts consisted of a large and easily identified vessel. Given the limited numbers of intrahepatic \((n = 1)\) and multiple acquired extrahepatic shunts \((n = 0)\), additional studies are necessary to clarify the value of CE-MRA in the diagnosis of these types of abnormalities. Visualization of a shunt on MIP images depends on the point of view, and it is therefore necessary to obtain a 360° MIP at different angles.26 In inconclusive studies, improved anatomic detail may be achieved by using subvolume MIPs in addition to the full volume MIP.25 CE-MRA was a valuable tool for diagnosis of extrahepatic PSS in nine dogs and an intrahepatic PSS in one dog as well as for surgical planning. Preoperative detailed three-dimensional anatomic information can guide the surgeon and allow targeted preparation of the shunt vessel. CE-MRA is therefore another useful tool for imaging abdominal and portal vasculature and for the diagnosis of PSS.

ACKNOWLEDGMENT
The authors thank Professor Pat Gavin for his critical review of the paper.
REFERENCES