CHAPTER 5

Standard planes for ultrasonographic identification and characterization of congenital portosystemic shunts and acquired portosystemic collaterals in dogs

based on the article by

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Standard planes for ultrasonographic examination of the portal system in dogs

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Summary

Seven planes were used to visualize the portal system in dogs that were suspected of having portosystemic shunting. To diagnose or to rule out portosystemic shunting, the right portal branch, the left gonadal vein, and the portal vein immediately caudal to the portal bifurcation as well as at the level of the splenic vein need to be imaged. In left lateral recumbency, transverse planes via the right intercostal spaces were used to find the right portal branch. Longitudinal planes, caudal to the last right rib, were used to reveal left-sided intrahepatic porto-caval shunts, and the extrahepatic spleno-caval and spleno-azygos shunts. In right lateral recumbency, longitudinal planes via the left abdominal wall were used to reveal the extrahepatic congenital shunts that arise from the right gastric vein, and to visualize the dilated left gonadal vein, which is the result of spleno-renal collateral-circulation, as it enters the left renal vein from caudal.
Introduction

Portosystemic shunting occurs when anomalous veins allow the portal blood to directly enter the systemic veins without flowing first through the hepatic sinusoids. Portosystemic shunting is thought to be congenital if a single (or double) anomalous vein is present without a concurrent portal hypertension, whereas acquired portosystemic collaterals are formed as a result of a compensatory mechanism due to sustained hepatic or prehepatic portal hypertension. Portosystemic shunting is suspected based on the history, clinical and laboratory findings, however direct visualization of the aberrant vein is essential for a definitive diagnosis because elevated blood ammonia levels can be caused not only by congenital portosystemic shunts (CPSSs), but also by acquired portosystemic collaterals (APSCs) and urea cycle enzyme deficiency. Differentiating these three conditions non-invasively is crucial because only CPSSs require surgical treatment, the other two do not.

For diagnostic imaging, angiography was the first modality that has been used and is still the most frequently used technique. The interpretation of the portographic images is simple and the differentiation of APSCs from CPSSs, and intra- from extrahepatic CPSSs is possible. However, portography is a time-consuming and invasive procedure that involves radiation. Although scintigraphy is the gold standard diagnostic imaging technique to detect as well as to exclude portosystemic shunting, it does not allow differentiation of CPSSs from APSCs. Computed tomography and MRI give detailed anatomic information of the vessels, however cannot determine the flow-direction in them, moreover both procedures are time-consuming and require general anesthesia. Ultrasonography has been used for diagnostic imaging of CPSSs since the 1980’s and has become popular because the examination is quick, non-invasive, does not require anesthesia or radiation, and the abdominal organs can be simultaneously evaluated. Currently no any other modalities can compete with the advantages of color Doppler ultrasonography in abdominal vascular imaging, however veterinarians tend to rely on the results of other or additional diagnostic procedures (e.g. explorative laparotomy and portography) because of the reported low sensitivity and specificity of ultrasound. The reason for the insufficient accuracy of the published ultrasound-studies could be that (1) no standardized examination protocol has been used; and (2) no descriptions have been available how the different types of CPSSs can be recognized and differentiated from one another. Moreover, the few reported studies focus only on some aspects of CPSSs, and the ultrasonographic features of APSCs are only superficially, or not discussed at all. Our aim is to describe an examination protocol for systematic ultrasonographic evaluation of the canine portal system. This protocol has allowed us not only to recognize and characterize the different types of CPSSs and APSCs accurately, but also to exclude portosystemic shunting in a large number of patients.

Description of the technique

Abdominal ultrasound examinations were performed in conscious dogs. Hair was clipped over the entire abdomen and the region of the last few right ribs, and contact gel was applied. First, a routine B-mode real time abdominal ultrasound examination was performed [ATL (Advanced Technology Laboratories) HDI 3000 high definition
Color Doppler parameters were adjusted with care so that a vessel would be uniformly colored. Namely, the color gain was set so that color signals would be seen in the entire lumen of a given vessel, but not outside the vessel. The pulse repetition frequency (PRF) was also appropriately adjusted, since a given PRF-setting is able to detect only a range of velocities. If the PRF is set too high, slow flow may be missed when the flow-velocity in a vessel is lower than the lower limit of the velocity-range that belongs to that PRF-value. When the flow-velocity is higher than the upper limit of the velocity-range, then aliasing artifact occurs. Traditionally, flow towards the transducer is coded with red, and flow away from the transducer with blue. Higher flow-velocities are coded with lighter shades of the appropriate color. If a velocity is higher than the upper limit of the velocity range, then no more lighter shade is available of the appropriate color, therefore these velocities will be coded with the wrong color, i.e. the color that indicates flow towards the opposite direction (blue instead of red).

Plane-1: transverse intercostal section in left lateral recumbency as a starting point—The transducer was placed in one of the last right intercostal spaces. The aim was to find the intercostal space through which only the liver was seen without the right kidney, and the cross-sections of the aorta, the caudal vena cava (CVC) and the portal vein trunk (PV) could be visualized. When the right kidney appeared in the initial image, then the transducer was angled cranially or slided to a more cranial intercostal space, whereas, when air-containing lungs appeared, the transducer was angled caudally or slided to a more caudal intercostal space. When the PV could not be imaged because of the gastrointestinal gas, the transducer was shifted dorsally within the same intercostal space and directed ventromedially.

Plane-2: transverse intercostal section in left lateral recumbency to image the right portal branch—Starting from plane-1, the PV was followed by angling or sliding the transducer cranially to the point where the longitudinal image of the right portal branch appeared.

Plane-3: transverse intercostal sections in left lateral recumbency to image congenital extrahepatic portosystemic shunts—Starting from plane-2, the transducer was gradually slided caudally keeping the PV and CVC in the image, until the level where the cranial mesenteric artery originated from the aorta. Scanning was performed first with B-mode, then was repeated with color Doppler mode. The aim was to look for a direct connection between the PV and CVC, or for a vessel that originated from the PV with a hepatofugal flow direction (away from the PV).

Plane-4: longitudinal section in left lateral recumbency to image the portal vein and the left divisional intrahepatic congenital portocaval shunts as well as the congenital extrahepatic portosystemic shunts—Longitudinal images of the PV and of the main portal branches were obtained with a transducer placed immediately caudal to the last rib and directed craniomedially. To find the PV, first the longitudinal image of the aorta was
obtained immediately ventral to the vertebrae. By ventral angulation of the transducer, the CVC became visible. Further ventral angulation resulted in the longitudinal image of the PV at the point where the splenic vein entered the PV. Firm transducer-pressure was often necessary to image the portal bifurcation.

In deep-chested and in large dogs the PV could not be visualized via the right flank, hence an alternative approach was used, namely starting from plane-1 the transducer was rotated by 90° to obtain a longitudinal image of the PV intercostally.

**Plane-5: longitudinal sections via the ventral abdominal wall in dorsal recumbency as an alternative for plane-4**—To find the PV in dorsal recumbency, the dog was slightly tilted towards the sonologist, and the right kidney with the caudate liver lobe was imaged first. Then the transducer was angled a bit ventromedially to image the CVC, then further ventromedially to image the PV. To image the portal bifurcation, the PV was followed cranially. The transducer had often to be pushed firmly to move away the gas-filled intestinal loops.

**Plane-6: longitudinal sections via the left lateral abdominal wall in right lateral recumbency to image the congenital extrahepatic right gastric-caval and right gastric-azygos shunts**—The transducer was placed immediately caudal to the last left rib longitudinally and the PV was imaged at the hilus of the liver. Imaging the PV using this approach was rather difficult and was only necessary when using plane-3 an extrahepatic CPSS was suspected, but its entire visualization was impossible.

Another way to find the right gastric-caval shunts was to follow the hepatic artery from its origin to the liver, since the hepatic artery crossed the wide shunt-loop. To find the hepatic artery, the celiac artery was imaged as it originated from the aorta, cranial to the left kidney. The hepatic artery is the widest branch of the celiac artery, which courses cranially to the liver between the PV and the CVC. Color Doppler mode helped to find the hepatic artery, when the gray scale resolution was insufficient to visualize this thin vessel. The color signals of the hepatic artery indicated higher flow velocity compared to that of the CVC and the PV.

**Plane-7: longitudinal sections via the left lateral abdominal wall in right lateral recumbency to image the dilated left gonadal vein, i.e. acquired spleno-renal collaterals**—The CVC was imaged in longitudinal section by placing the transducer immediately ventral to the lumbar vertebrae and caudal to the left kidney. Keeping the longitudinal image of the CVC, the transducer was slided cranially to image the left renal vein entering the CVC. With B- and color Doppler modes a vein was searched that entered the left renal vein from caudal.

**Results**

**Dogs**

Twenty clinically healthy adult beagles of both sexes with normal serum bile acids and bilirubin levels as well as normal plasma alanine transaminase and alkaline phosphatase activities were examined to establish the normal abdominal vascular ultrasound anatomy. In addition to these normal dogs, 90 client-owned dogs with high
blood ammonia levels were examined. These patients were selected from the dogs that were examined because of hyperammonemia at the Companion Animal Clinic of Utrecht University between July 2000 and December 2002. Selection criteria were (1) laparotomy or necropsy or liver biopsy or scintigraphy was performed depending on the ultrasonographic diagnosis to confirm the ultrasonographic findings, and (2) the ultrasound examination was performed by the first author.

Findings in plane-1

Normal anatomy. From dorsal to ventral the cross-sections of the aorta, CVC and PV were seen; their cross-sectional areas were roughly equal (Fig 1A). The CVC was often latero-laterally collapsed.

Congenital intrahepatic porto-caval shunts. The images did not differ from normal, except for the presence of a dilated, hence clearly recognizable hepatic artery between the CVC and PV (Fig 1B). The hepatic artery was a pulsating vessel with a smaller diameter compared to that of the PV.

Congenital extrahepatic spleno-caval, spleno-azygos, right gastric-caval and right gastric-azygos shunts. The PV was thinner than the aorta, sometimes to such an extent that could not even be visualized.

Acquired portosystemic collaterals. Visualization of the PV was often hindered by ascitic fluid and the cranially displaced intestines due to the small liver. If the PV was visible, its diameter was either smaller or larger compared to the aorta.

Figure 1.

Plane-1, transverse section via one of the last right intercostal spaces with the dog in left lateral recumbency as the starting point of the systematic ultrasound examination of the portal system.

A. Gray scale image of the liver of a healthy male adult beagle. From dorsal to ventral the cross-sections of the aorta (AO), caudal vena cava (CVC) and portal vein (PV) are seen. The cross-sectional areas of the three vessels are approximately equal.

B. Color Doppler image of the liver of a 5-month-old female Labrador retriever with a persistent ductus venous. In the color box from dorsal to ventral the cross sections of the caudal vena cava (CVC), hepatic artery (HA) and portal vein (PV) are seen. The hepatic artery is wider than in a healthy dog. The flow velocity in the HA is faster than that of the CVC and PV.
Findings in plane-2

Normal anatomy. The right portal branch was consistently found as a well-defined vein originating from the PV and running dorsolaterally to the right while becoming gradually thinner due to ramification (Fig 2A).

Congenital intrahepatic porto-caval shunts. Each right-sided intrahepatic CPSS originated from the right portal branch as its direct continuation. The right portal branch was wider than normal and did not get thinner towards the periphery. The first segment of the shunt consistently ran dorsolaterally to the right, like a normal right portal branch, but then instead of ramification, it turned medially to enter the CVC (Figs 2B, 2C). With little transducer-manipulation the entire course of the shunt could be traced to its caval termination.

Left-sided intrahepatic CPSS was suspected, when the findings described in plane-1 were compatible with an intrahepatic CPSS, and the right portal branch was absent or very thin (Fig 2D). Often a hepatic artery branch was found at the place where the right portal branch was expected (Fig 2E). On B-mode images this artery looked like a very thin right portal branch, but color Doppler revealed much faster flow in it than in a portal branch could be expected, moreover pulsed-wave Doppler mode showed low-resistance arterial spectrum in it confirming that this thin vessel was actually a hepatic artery branch, which coursed next to the hypoperfused and hypoplastic right portal branch.

Congenital extrahepatic spleno-caval, spleno-azygos, right gastric-caval and right gastric-azygos shunts. The right portal branch as well as the PV itself were usually so thin that they could not be visualized either on B-mode or on color Doppler images (Fig 2F). When they were wide enough to be seen (exceptionally), the blood flow velocity was either undetectably slow or very slow hepatopetal in them.

Acquired portosystemic collaterals. The right portal branch could only be exceptionally visualized because of the ascites and the small size of the liver. When it was visualized, it was either thinner or wider than normal, but showed normal arborization and undetectably slow flow (i.e. no flow with the lowest possible PRF-setting). When it was thin, then the PV was also thin; when it was wide, then the PV was also wide.

Findings in plane-3

Normal anatomy and congenital intrahepatic porto-caval shunts. Immediately caudal to the portal bifurcation, the gastroduodenal vein could occasionally be imaged as it entered the ventral aspect of the PV from the right; however the gas-filled descending duodenum often hindered its visualization. Sliding the transducer further caudally, the splenic vein could be seen entering the left aspect of the PV from ventrolateral direction.
Figure 2.
See legend on opposite page.
Figure 2.

Plane-2, transverse section via a right intercostal space with the dog in left lateral recumbency to image the right portal branch, cranial to plane-1.

A. Normal right portal branch (PVbrR) at the point of its origin from the portal vein (PV) in a healthy adult male beagle. The right portal branch is thinner than the PV and becomes gradually thinner towards the periphery due to ramification. The right portal branch runs dorsolaterally and to the right. CVC caudal vena cava.

B. Right divisional congenital intrahepatic portocaval shunt. Gray scale ultrasound image of an intrahepatic porto-caval shunt that originates from the right portal branch (PVbrR) in a 5.5-month-old male Labrador retriever. In this single image the direct connection between the right portal branch and the caudal vena cava (CVC) can be appreciated. The right portal branch is as wide as the portal vein (PV) and remains wide towards the periphery.

C. Central divisional congenital porto-caval shunt. Gray scale ultrasound image of a 4-month-old male Irish wolfhound mixed breed dog with a short intrahepatic porto-caval shunt (SH) that originates from the right portal branch (PVbrR). Compare the length of the shunt with the one shown in Figure 2B! CVC caudal vena cava, PV portal vein.

D. Gray scale ultrasound image of the right portal branch (PVbrR) in a 5.5-month-old male Bernese mountain dog with an intrahepatic porto-caval shunt that originates from the left portal branch (persistent ductus venosus). The portal vein (PV) has similar diameter to that of the caudal vena cava (CVC), however the right portal branch is very thin.

E. Color Doppler image of the right portal branch in a 1.5-year-old cairn terrier with a congenital extrahepatic spleno-caval shunt. The caudal vena cava (CVC) is well recognizable, however at the place of the portal vein (PV) and right portal branch (PVbrR), only the walls of these collapsed vessels can be seen as hyperchoic structures. The color signs originate from the adjacent hepatic artery branch (HA hepatic artery branch of the right lateral liver lobe). AO aorta. (Full color illustration on page 181.)

F. Undetectable right portal branch in plane-2 of a dog with a left divisional congenital intrahepatic portocaval shunt. An artery is seen at the place where the right portal branch is expected. The localization and course of this vessel is compatible with a right portal branch, but the flow velocity is very high in it (color aliasing). The hepatic artery and portal branches run normally adjacent to each other, but in this case the portal branch is undetectably thin. Dotted arrows indicate the direction of blood flow, CVC caudal vena cava, HA hepatic artery branch of the right lateral liver lobe, PV portal vein. (Full color illustration on page 180.)
Color Doppler mode revealed hepatopetal flow in the splenic vein. Slightly caudal to this point, the origins of the celiac and cranial mesenteric arteries from the aorta could be seen. Both arteries ran ventrally.

**Congenital extrahepatic portosystemic shunts.** The origin of the cranial loop of the right gastric-caval shunts were sometimes seen (Fig 3A), however the gastrointestinal gas often hindered their visualization. Therefore, plane-6 was used when a CPSS with a right gastric vein origin was suspected based on the findings in planes-1, -2 and -3. The point where the shunt entered the CVC could often be detected, but the course of the shunt-loops could not be visualized.

The whole length of spleno-caval shunts, and the origin of spleno-azygos shunts were always visualized. Spleno-caval CPSSs made a short loop on the left side of the PV and CVC. The direct connection was usually appreciated on B-mode images (Fig 3B), however occasionally, when the shunt did not appear on B-mode images because of the insufficient gray scale resolution, color Doppler mode was necessary to visualize the shunt.

![Ultrasonograms of the two possible origins of canine congenital extrahepatic portosystemic shunts scanned from plane-3 with the dogs in left lateral recumbency.](image)

A. Color Doppler image of the origin of a right gastric-caval shunt in a 10-month-old female Maltese dog. The gastroduodenal vein (GDV) seems to enter the shunt (SH) itself; in fact the red part of the shunt belongs to the gastroduodenal vein and the shunt originates at the point of the blue-red transition. The shunt drains not only the blood of the gastroduodenal vein, but also the blood of the portal vein (PV). The entire shunt cannot be visualized from this approach. Dotted arrows indicate the direction of blood flow, CVC caudal vena cava, HA hepatic artery. (Color version on page 180.)

B. B-mode ultrasound image of a congenital extrahepatic spleno-caval shunt in a 3.5-month-old female Jack Russell terrier in plane-3. Cross sections of the aorta (AO), caudal vena cava (CVC) and portal vein (PV) are shown. Between the CVC and the PV the hepatic artery (HA) is seen. A short anomalous vein (SH) makes direct connection between the PV and the CVC on their left side. The diameters of the shunt and the PV are about equal. Note that not only the origin, but the entire shunt can be visualized in a single image from this approach.
**Acquired portosystemic collaterals.** The visualization of the PV was often difficult because of the presence of ascites and the cranially displaced intestines due to a small liver. When the PV was imaged, the PV had uniform diameter along its whole length. The origin of an APSC was occasionally found at the region where congenital extrahepatic spleno-caval shunts were expected to arise, i.e. an anomalous vein with hepatofugal flow.

**Findings in plane-4**

**Normal anatomy.** The splenic vein was seen to enter the PV from caudolateral direction from the left. Following the PV cranially, the portal bifurcation was seen with the wider left and the thinner right portal branch. Both branches became gradually thinner towards the periphery (Fig 4A).

**Congenital intrahepatic porto-caval shunts.** The PV looked similar to that of normal dogs. Following the PV cranially, an intrahepatic CPSS appeared as the direct continuation of the PV, and entered the CVC. Plane-4 did not allow the differentiation whether the intrahepatic CPSSs originated from the right or left portal branch, however in plane-2 the right- and central-divisional intrahepatic CPSSs could already be diagnosed and the left-divisional ones suspected. Plane-4 was only used to confirm the presence of left-divisional intrahepatic CPSSs by direct visualization of the porto-caval connection (Fig 4B). Since the intrahepatic CPSSs that originated from the left portal branch coursed adjacent to the diaphragm, plane-4 allowed their better visualization than plane-2 because the gas-containing intestinal loops could be pushed away with the transducer.

A. Normal portal bifurcation in a 8-week-old mixed breed dog with hypoalbuminaemia. Color Doppler image of the portal vein (PV) at the hilus of the liver with the portal bifurcation. Note that the left portal branch (PVbrL) is wider than the right one (PVbrR) and they become gradually thinner towards the periphery. The image was made via the right flank with the dog in left lateral recumbency.

B. Intrahepatic porto-caval shunt that originates from the left portal branch in a 9-month-old hovawart. The portal trunk (PV) continuous via a wide and tortuous anomalous vessel (SH) and terminates in the caudal vena cava (CVC). The image was made in plane-5. d diaphragm
**Congenital extrahepatic spleno-caval and spleno-azygos shunts.** Using plane-4, the PV-segment cranial as well as caudal to the CPSS-origin could also be seen in addition to the shunt, and the direction of flow could be determined in them (**Fig 5**). In cases of spleno-caval CPSSs, the termination of the CPSS could be found with little transducer-manipulation by following the shunting vessel. In cases of spleno-azygos shunts, the shunt could be traced to the point where it entered the thorax through the diaphragm. Occasionally the PV-segment cranial to the point where the gastroduodenal vein entered the PV could also be imaged.

![Image](image-url)

**Figure 5.**
Color Doppler ultrasound image of the portal vein in longitudinal section from plane-4. The transducer is placed longitudinally, caudal to the last right rib, with the dog in left lateral recumbency. Dotted arrows indicate the direction of blood flow.

A. Congenital extrahepatic spleno-caval shunt (SH). Cranial to the shunt-origin the direction of portal blood flow is hepatofugal. The portal vein cranial to the shunt-origin (PVcrSH) is thinner than the portal vein caudal to the shunt-origin (PVcaudSH). The shunt originates from the portal vein, very close to the point where the splenic vein (SPLV) enters the portal vein. (Full color illustration on page 180.)

B. Normal portal vein (PV) in a Yorkshire terrier. The diameter of the portal vein is uniform along its whole length. GDV gastroduodenal vein, SPL splenic vein, HA hepatic artery. (Full color illustration on page 180.)

**Congenital extrahepatic right gastric-caval and right gastric-azygos shunts.** Occasionally the origin of the dilated right gastric vein was visualized using this view, but not the course of the cranial loop of the shunt. The caudal shunt-loop (when it was present) was regularly visualized, which originated at the same point as a congenital extrahepatic spleno-caval shunt, however it coursed cranially, unlike a spleno-caval shunt, which coursed dorsally. The PV cranial to the origin of the caudal shunt-loop was always seen, and the flow-direction was always hepatopetal in it. The anastomosis between the cranial and caudal loops of the shunt could never be visualized with ultrasound.

**Acquired portosystemic collaterals.** This view made the assessment of portal flow-velocity and of portal flow-direction possible. The origin of APSCs arising from the PV could also be seen at the region where congenital extrahepatic spleno-caval shunts arise. It was impossible to image the PV-segment that was cranial to the entering point of the gastroduodenal vein in any dog with APSCs.
Findings in plane-5
The findings were the same as described under plane-4, but in some cases plane-5 allowed better visualization of the shunt or of the PV (Fig 4B), and provided better incidence angles for Doppler studies.

Findings in plane-6
*Congenital extrahepatic right gastric-caval or right gastric-azygos shunts.* Usually when the PV was being searched, a large-caliber anomalous vein (i.e. the shunt) appeared just under the body wall, even before the PV was actually found. The diameter of this CPSS was comparable to that of the CVC. Following the shunt cranially it seemed to originate from the PV, at the hilus of the liver, making a 90° angle (Fig 6A). From its origin, the shunt was followed to its termination with or without the help of color Doppler mode (Fig 6B). The PV cranial to the shunt-origin could never be visualized.

![Figure 6](image)

**Figure 6.** Congenital extrahepatic right gastric-caval shunt, the cranial loop. Dotted arrows indicate the direction of flow. **A.** Color Doppler image of the origin of the cranial loop of a right gastric-caval shunt in a 6.5-month-old female Yorkshire terrier in right lateral recumbency, from plane-6. The shunt (SH) runs towards the left body wall making a 90° angle with the portal vein (PV). (Full color illustration on page 181.) **B.** The continuation of the shunt that is shown in Figure 6A (followed caudally). The right gastric-caval shunt (SH) terminates in the caudal vena cava (CVC). Note the large-caliber shunting vessel (SH) immediately under the left body wall. CA celiac artery, CMA cranial mesenteric artery. (Full color illustration on page 181.)

Normal anatomy, congenital intrahepatic porto-caval shunts, congenital extrahepatic spleno-caval and spleno-azygos shunts, acquired portosystemic collaterals.
The large-caliber anomalous vein described above was absent. The right gastric vein is so thin that cannot be visualized ultrasonographically.

Findings in plane-7
*Normal anatomy, congenital intra- and extrahepatic portosystemic shunts.* Caudal to the left kidney 2 great vessels, namely the aorta and the CVC were seen; the aorta was located more to the left. The left gonadal vein could never be visualized. The left renal artery (occasionally double) ran adjacent to the left renal vein and could be recognized even on gray scale images by its smaller diameter and pulsation.

*Acquired portosystemic collaterals.* The dilated left gonadal vein could always be seen entering the left renal vein from caudal (Fig 7); except for the cases of tense ascites,
when not even the CVC could be visualized. When the left gonadal vein was very wide (Fig 7A), it appeared as a third great vessel on the left side of the aorta. Many small tortuous veins (portosystemic collaterals) could often, but not always be seen around the left renal vein (Fig 7B).

Figure 7.
Acquired portosystemic collaterals.
(Full color illustrations on page 181.)

A. Color Doppler image of a dilated left ovarian vein in a 6.5-year-old female Jack Russell terrier with sustained portal hypertension due to primary hypoplasia of the portal vein, from plane-7. Dotted arrows indicate the direction of blood flow. A ascites, CVC caudal vena cava, LOV left ovarian vein, LRV left renal vein.

B. Color Doppler image of several tortuous collateral veins caudal to the left kidney in a 5-month-old boxer with sustained portal hypertension due to primary hypoplasia of the portal vein, from plane-7.

Accuracy
The protocol described above allowed us to rule out portosystemic shunting non-invasively when hyperammonemia was the result of a laboratory error (2/90) or of a urea cycle enzyme deficiency (9/90). The abdominal ultrasonographic findings of the 90 hyperammonemic dogs are shown in Table 1. Acquired portosystemic collaterals were identified in all cases. None of the dogs with APSCs or with normal vascular anatomy underwent a laparotomy, whereas all the dogs with CPSS underwent a surgical shunt-ligation.
Table 1.
Ultrasonographic findings in 90 dogs with hyperammonemia

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In cases of CPSS, the shunting vessel was followed from its origin to its termination. One exception was a 5-month-old Weimaraner, in which the shunting vessel could not be visualized ultrasonographically, not even when the dog was sedated, though the ultrasonographic findings were compatible with a left-sided intrahepatic CPSS (i.e. wide PV and left portal branch, undetectable right portal branch, no extrahepatic CPSS or APSCs). Laparotomy revealed a left-sided intrahepatic CPSS. In cases of portal hypertension with APSCs, the direct connection between the portal and the systemic veins could only exceptionally be appreciated, however a dilated left gonadal vein was always seen.

In 4 dogs the ultrasonographic diagnosis was congenital extrahepatic spleno-caval shunt, whereas during surgery the termination of the shunt could not be visualized in the abdomen, hence they were reported to be congenital extrahepatic spleno-azygos shunts. In every other CPSS-cases the ultrasonographic diagnosis was in agreement with the surgical findings.

Discussion

Previous studies that aimed ultrasonographic differentiation of CPSSs from other diseases reported 74-95 % sensitivity and 57-100 % specificity. The reason why not each extrahepatic CPSS was recognized could be that in two studies only a right intercostal approach was used. As we showed, the congenital extrahepatic right gastric-caval shunts cannot be readily diagnosed from this view, because the visualization of the cranial shunt-loop requires a right lateral recumbency, whereas the caudal shunt-loop can only be seen
via the right flank in a longitudinal section. The possible explanation why extra- and intrahepatic CPSSs were mistaken in these studies could be that the evaluation of the abdominal vasculature was not systematic and the right portal branch was not regularly imaged. Indeed, congenital extrahepatic spleno-caval shunts seem to be surrounded by liver when they are scanned via a right intercostal approach. Our systematic approach allowed us to diagnose both CPSSs and APSCs by ultrasound with 100 % sensitivity, 100 % specificity and 100 % accuracy. We did not consider the case of the Weimaraner false negative because though the direct connection of the left portal branch and CVC could not be visualized ultrasonographically, the morphology of the abdominal vessels was compatible with a left sided intrahepatic CPSS. In addition to the use of our scanning protocol, a high accuracy could only be achieved with the use of a high quality ultrasound machine with an excellent gray scale resolution. Using color Doppler is not essential, however it greatly facilitates the diagnosis of abdominal vascular diseases, especially if the ultrasound system is equipped with a sensitive color Doppler mode and the sonographer is familiar with the Doppler techniques.

Accurate recognition of CPSSs by ultrasound is only possible, if the anomalous vein is followed from its origin to its termination. Finding the point where a CPSS enters the CVC may be easier than finding the origin of a CPSS, however finding a vein that enters the CVC does not mean that it is a CPSS because several other veins enter the CVC. If the origin and the course of a suspected CPSS is not visualized, a normal right renal or phrenicoabdominal vein could be mistaken with a CPSS. When a vein that is suspected to be a CPSS is found to enter the CVC, it has to be traced from its termination to its origin, i.e. to the PV. In contrast, when a vein that originates from the PV or from a portal tributary displays hepatofugal flow, it is surely an extrahepatic CPSS or an APSC, even without knowing the point of its termination because in normal animals veins only enter the PV and do not originate from it.

In our opinion, technically the most difficult type of CPSS to find and visualize is the left divisional intrahepatic CPSS because it runs very close to the diaphragm. Therefore its visualization via the intercostal spaces is usually impossible, whereas its scanning via the right flank requires hard transducer-pressure because of the cranially displaced intestines due to the small liver, which causes discomfort to the dog, hence they do not usually stay still making the examination even more difficult.

Diagnosing APSCs ultrasonographically requires a different approach compared to that of the CPSSs because the collateral veins only occasionally arise directly from the PV, moreover they are thin and tortuous and most of the times are hidden among the intestines. Therefore, their origins and courses can only exceptionally be revealed. The dilated left gonadal vein, i.e. the termination of the spleno-renal collaterals, however was found to be a highly specific and sensitive indicator of APSCs, and its ultrasonographic visualization is simple (Chapter 4).

In sum, ultrasonography is a highly sensitive and specific, non-invasive diagnostic method to diagnose or exclude CPSSs and APSCs in dogs. Excluding portosystemic shunting is not only based on the fact that no anomalous veins could be found, but also on the fact that the abdominal vessels of a dog with normal vascular anatomy look different from those of a dog with portosystemic shunting. The 4 sites that always need to be imaged when a portal vein anomaly is suspected are (1) the right portal branch, (2) the left gonadal vein, (3) the portal vein at the level of the celiac artery (splenic vein) and (4) the portal vein immediately caudal to the portal bifurcation (right gastric vein and gastroduodenal vein).
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References
