Diagnostic Imaging of Dogs with Suspected Portosystemic Shunting

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ABSTRACT: Contrast radiography, ultrasonography, and scintigraphy may all be used in the diagnostic workup of dogs suspected of having portosystemic shunting (PSS). Contrast radiography (portal venography), although invasive, is the definitive method for demonstrating shunts in any anatomic site. Ultrasonography is a convenient, noninvasive method for diagnosing congenital PSS, determining shunt morphology, and assessing other abdominal structures. Doppler ultrasonography is a more demanding technique that may be used to look for signs of portal hypertension and acquired PSS. Scintigraphy is a useful alternative noninvasive technique for diagnosing all types of PSS and is a method for measuring the proportion of portal blood that bypasses the liver. There appears to be limited potential for prognosis based on any of these imaging modalities.

Portosystemic shunting (PSS) is a well-recognized condition in dogs that causes a variety of clinical signs, including stunted growth, polyuria and polydipsia, vomiting, ataxia, seizures, and altered behavior.1 PSS may be classified as primary or secondary. Primary (congenital) PSS occurs as a single (or occasionally double) macroscopic vascular connection between the portal vein or a portal tributary and the caudal vena cava or other systemic vein. Congenital PSS may be divided anatomically into intrahepatic and extrahepatic forms.2 Intrahepatic PSS, which occurs mainly in large-breed dogs, is described according to its position in the liver as left-, central-, or right-divisional3 (Figure 1). The morphology of left-divisional shunts is compatible with patent ductus venosus. Irish wolfhounds are predisposed to patent ductus venosus, whereas Old English sheepdogs, golden and Labrador retrievers, and Australian cattle dogs are predisposed to central-divisional shunts.2,5 Extrahepatic PSS usually connects a major tributary of the portal vein, such as the splenic or gastric vein, with the caudal vena cava (Figure 1). Occasionally, the shunting vessel drains into the azygos vein. Congenital extrahepatic PSS usually affects small breeds, particularly terriers, miniature schnauzers, miniature poodles, shih tzus, and Lhasa apsos.1,4
Secondary (acquired) PSS takes the form of multiple, small extrahepatic vessels in the omentum or retroperitoneum near the kidneys, which drain directly or indirectly into the caudal vena cava. Acquired PSS develops in response to chronic portal hypertension, which occurs most often as a result of hepatic fibrosis or cirrhosis.

Breed-associated hepatopathies may lead to portal hypertension and acquired PSS in German shepherds, American cocker spaniels, Doberman pinschers, and Labrador retrievers.

Portal hypertension may also occur in young dogs secondary to congenital anomalies, such as portal vein atresia or hepatic arterioporal fistula.

**ROLE OF DIAGNOSTIC IMAGING**

The role of diagnostic imaging in dogs with signs of PSS is to determine whether PSS is present, to determine whether the lesion is congenital or acquired, and to assess the severity of the shunting. Also, diagnostic imaging enables preoperative morphologic assessment of intrahepatic PSS. This is useful because the morphology largely dictates which techniques may be used for surgical treatment, thereby possibly reducing surgical time. Complications occur commonly during surgical treatment of dogs with intrahepatic shunts, particularly if surgery is prolonged because the shunt is difficult to find.
The diagnostic imaging techniques reported most frequently in relation to PSS in small animals are portal venography, ultrasonography, and scintigraphy. Radiography and ultrasonography provide information principally about the structural abnormalities in dogs with PSS, whereas scintigraphy enables assessment of abnormal blood flow. Each of these imaging modalities has different strengths and weaknesses (Table 1).

**Radiography**
Survey radiography of the liver enables a limited evaluation of its position, size, shape, and opacity. The size of the liver is usually inferred from the appearance of its caudoventral border as seen on a lateral radiograph and from the position of the stomach or spleen, which may be displaced cranially when the liver is small. A small liver usually has a blunt caudal border that lies within the costal arch. In dogs, hepatic volume is usually determined based on a subjective assessment. There is a fair correlation between linear dimensions of the liver and its volume, but attempts to estimate hepatic volume from abdominal radiographs of dogs have proved imprecise.

**Contrast Radiography**
Portal venography, although invasive, is the definitive method for demonstrating shunts in any anatomic site. Various techniques for injecting contrast medium into the portal vein have been described, including operative mesenteric portography, cranial mesenteric angiography, and percutaneous splenoprtography. Portal venography is the optimal method for assessing shunt location (intra- versus extrahepatic) and morphology. Operative mesenteric portography, although invasive, is a relatively simple and direct technique. It involves taking radiographs immediately after injecting contrast medium into a catheter placed surgically in a jejunal vein; therefore, it is necessary either to have a radiography room that is clean enough for abdominal surgery or to use mobile radiographic equipment in surgery. This technique produces good opacification of the portal vein and usually enables PSS to be readily detected (Figure 3). It is frequently used in combination with surgery to treat congenital PSS, and the same jejunal vein catheter is used to measure portal blood pressure during shunt attenuation.

Alternatively, selective catheterization of the cranial mesenteric artery via a femoral arteriotomy and injection of contrast medium opacifies the portal vein after circulation through the intestinal vessels. This technique is used less often than operative mesenteric por-

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**Table 1. Comparison of Imaging Techniques for Detecting Features of Portosystemic Shunts in Dogs**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Survey Radiography</th>
<th>Portal Venography</th>
<th>Ultrasonography</th>
<th>Scintigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced hepatic volume</td>
<td>+</td>
<td>++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Anomalous vessel</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Intra- versus extrahepatic location</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Portal hypertension</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Shunt fraction</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Renal enlargement</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Urate urolithiasis</td>
<td></td>
<td></td>
<td>++</td>
<td></td>
</tr>
</tbody>
</table>

+ = Limited information; ++ = useful information; +++ = detailed information, accurate assessment often possible.
ography because it is technically more demanding (requiring image intensification during catheter placement) and, if a congenital shunt is detected or a liver biopsy is required, a laparotomy is indicated anyway.

It is typical to repeat the intraoperative portal venogram immediately after ligation of a shunt. This serves two purposes: It helps confirm that the correct vessel has been ligated (i.e., there is no second shunt), and it enables assessment of the intrahepatic portal vasculature (Figure 4). Poor opacification of the lobar portal branches on a postligation portal venogram might occur if they were small or nonpatent and would suggest hypoplasia of the portal vessels. However, the appearance of portal branches in the postligation portal venogram does not help predict whether the patient’s condition will be improved after surgery. Of 26 dogs that had very poor opacification of hepatic branches after shunt attenuation in a recent study, only 5 had a poor outcome and 21 did well.

**Ultrasonography**

**Two-Dimensional Gray-Scale Ultrasonography**

Ultrasonography is a rapid, convenient, noninvasive method for assessing PSS and a versatile imaging modality, enabling visualization of most congenital PSS and lesions affecting other abdominal structures as well as estimation of hepatic volume and vascularity (Table 2).

In dogs with congenital PSS, the liver is usually small and the caliber and number of visible intrahepatic vessels are reduced. Hepatic volume may be estimated ultrasonographically by measuring the maximal distance from the caudal tip of the liver to the diaphragm. There is a roughly linear relationship between this dimension and body weight; however, for a dog of any particular body weight, there is quite a wide normal range; hence confident conclusions are possible only when examining a dog with either a very small or very large liver. As for radiography, subjective evaluation of hepatic volume is also based on the position of the stomach or spleen and the shape of the caudal hepatic border, which usually appears blunted in ultrasonographic images of dogs with small livers.

The ability to examine large blood vessels makes ultrasonography a useful diagnostic test for congenital PSS in dogs. Ultrasonography has a greater than 90% accuracy rate for diagnosing congenital PSS. It is also possible to differentiate whether the shunt is intrahepatic or extrahepatic in nearly all affected dogs. Intrahepatic shunts appear as broad, curved, or tortuous vessels that connect the portal vein and the caudal vena cava. They may be visualized from a ventral window in a small dog, but the most useful approach is via an
affecting the hepatic parenchyma or the portal vein, such as signs of cirrhosis, hepatopetal fistula, or portal vein thrombosis.\textsuperscript{9,23,24}

Other ultrasonographic signs that may be observed in dogs with acquired PSS include congested spleen, peritoneal fluid, pancreatic edema, and urolithiasis (Table 2).\textsuperscript{9}

**Doppler Ultrasonography**

Doppler ultrasonography enables detection and measurement of blood flow in large vessels and has been used to investigate hepatic diseases that may alter portal blood flow (Figure 7).\textsuperscript{9,25} Normal portal blood flow is nonpulsatile with a mean velocity of approximately 15 cm/sec in unsedated dogs.\textsuperscript{9}

Congenital PSS represents a low-resistance path for blood to bypass the liver and enter the caudal vena cava; hence increased and/or variable portal blood flow is present in many affected dogs.\textsuperscript{20} Most congenital PSS is detectable using two-dimensional, gray-scale imaging, but occasionally in a dog in which the shunting vessel has not been found the diagnosis may be based on finding abnormally high, variable portal blood flow.\textsuperscript{9,20} Dogs with portal hypertension and acquired PSS may have reduced or reversed (i.e., hepatofugal) portal blood flow, and flow in portal tributaries (e.g., the splenic vein) may also be reversed.\textsuperscript{9,25} It is worth attempting to measure portal blood flow in animals with suspected hepatic insufficiency because portal hypertension may be present even if the hepatic parenchyma appears normal.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Congenital PSS</th>
<th>Acquired PSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatic volume</td>
<td>Usually reduced</td>
<td>Variable</td>
</tr>
<tr>
<td>Hepatic parenchyma</td>
<td>Attenuated vessels or reduced numbers of vessels</td>
<td>Diffuse or multifocal echotextural changes</td>
</tr>
<tr>
<td>Renal volume</td>
<td>Often increased</td>
<td>Usually normal</td>
</tr>
<tr>
<td>Anomalous vessel</td>
<td>Usually single; may be large, intra- or extrahepatic</td>
<td>Multiple, small, extrahepatic</td>
</tr>
<tr>
<td>Portal blood flow velocity</td>
<td>May be increased and variable</td>
<td>Reduced, sometimes hepatofugal</td>
</tr>
<tr>
<td>Other potential findings</td>
<td>Urinary calculi</td>
<td>Urinary calculi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dilated abdominal veins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Portal vein thrombosis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lesion impinging on portal vein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ascites</td>
</tr>
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<td></td>
<td></td>
<td>Pancreatic edema</td>
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</tbody>
</table>

**Table 2. Typical Ultrasonographic Findings in Dogs with Portosystemic Shunting**

<table>
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<tr>
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**Figure 4**—Operative mesenteric portal venogram of a congenital extrahepatic PSS before and after ligation of the shunting vessel. The portal vein (PV) appears hypoplastic, but there is fair opacification of intrahepatic portal veins (arrows); CVC = caudal vena cava.

**Figure 5**—Ultrasonographic diagnosis of acquired PSS is more difficult because the shunting vessels are usually small and do not occur in such consistent locations as congenital shunts. They may be observed in the retroperitoneum near the kidneys or medial to the spleen (Figure 6).\textsuperscript{9} The underlying cause of acquired PSS may be observed ultrasonographically if there are abnormalities affecting the hepatic parenchyma or the portal vein, such as signs of cirrhosis, hepatopetal fistula, or portal vein thrombosis.\textsuperscript{9,23,24} Other ultrasonographic signs that may be observed in dogs with acquired PSS include congested spleen, peritoneal fluid, pancreatic edema, and urolithiasis (Table 2).\textsuperscript{9}
Figure 5—Ultrasonography in dogs with congenital PSS. (A) Sagittal image showing a small liver (L). The positions of the diaphragm (D), stomach (St), and small intestine (SI) are also visible. (B) Right intercostal image showing a tortuous intrahepatic vessel (arrows); its position and morphology are compatible with a right-divisional shunt. (C) Right intercostal image showing the point at which an extrahepatic PSS (arrow) drains into the caudal vena cava (CVC; Ao = aorta; pv = portal vein).

Figure 6—Ultrasonography in dogs with acquired PSS. (A) Sagittal image showing peritoneal fluid (PF) and a liver with a heterogeneous echotexture and knobby surface (arrows). This combination of signs is typical of cirrhosis. (B) Close-up of the caudal pole of the left kidney (LK) and adjacent retroperitoneum in which several small irregular hypoechoic structures compatible with vessels are visible (arrows; CVC = caudal vena cava). (C) Color-flow Doppler image is positive for flow in these vessels.
Scintigraphy

Scintigraphy is a noninvasive, quantitative method for imaging normal physiologic processes and dysfunction that may occur as a result of disease. Scintigraphic images depict blood flow or metabolism in the body according to the distribution of a radioactive element (radioisotope) linked to a metabolite, which is detected using a gamma camera. These images principally reflect function, not structure, which is in contrast to the images obtained by radiography or ultrasonography. In many diseases, abnormal function precedes any morphologic changes. Scintigraphy has been used in dogs to examine hepatocyte function, excretion of bile, reticuloendothelial function of the liver, and portal blood flow.

For portal scintigraphy, a small amount of radioisotope is administered via a per-rectal catheter inserted into the colon, where it is absorbed into the portal system. A variety of radioisotopes are absorbed into the portal circulation from the colon, including $^{123}$I-iodoamphetamine and $^{99m}$Tc-pertechnetate. Pertechnetate is the most commonly used radioisotope for portal scintigraphy.

In a normal animal, the liver receives the radioisotope first via the portal vein, but if there is a PSS, the radioisotope bypasses the liver and initially reaches the heart (Figure 8). Note that the location or type of PSS cannot be determined scintigraphically because of the low spatial resolution of the gamma camera.

When a series of scintigraphic images are acquired after administering the radioisotope, the portal vein and liver are normally visualized after 10 to 14 seconds; it then takes another 8 to 14 seconds for the radioisotope to pass through the hepatic sinusoids into the hepatic veins, caudal vena cava, and heart (Figure 9). In a dog with PSS, the radioisotope usually accumulates in the heart before the liver. Quantitative analysis is possible using an imaging computer. Regions of interest (ROIs) are created around the liver and heart, and the accumulation of radioisotope in these ROIs is then measured over time (Figure 9). An estimate of the proportion of portal blood that bypasses the liver (shunt fraction [SF]) can be made by comparing the counts in the liver and heart after the radioactivity has entered the portal venous system using the following formula:

$$SF = \frac{\Sigma \text{Heart counts}_{0-12 \text{ sec}}}{\Sigma \text{Liver counts}_{0-12 \text{ sec}} + \Sigma \text{Heart counts}_{0-12 \text{ sec}}} \times 100\%$$

The SF is normally less than 15%. Most dogs with congenital PSS have an SF greater than 70%.

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**Figure 7**—Examples of Doppler spectra obtained from the portal vein. In a normal, unseated dog (left), portal flow is relatively uniform. Portal hypertension (top right) results in reduced velocity flow (in this instance, to a mean of 5 cm/sec). In dogs with congenital PSS (bottom right), flow may be increased and variable.

**Figure 8**—Scintigraphic images of a normal dog (left) and a dog with congenital PSS (right). Each image represents the distribution of radioisotope after injection into the colon. The majority of radioisotope is in the liver, with some reaching the heart after passing normally through hepatic sinusoids and the caudal vena cava. In the dog with PSS, the liver is barely visible because most of the injected radioisotope has reached the systemic circulation.
An alternative technique for portal scintigraphy involves ultrasound-guided injection of radiochemical directly into a splenic vein. This method of injection combined with the use of \(^{99m}\text{Tc}\)-labeled macroaggregated albumin, which is normally trapped in the hepatic sinusoids, provides scintigraphic images in which any activity in the lung is the result of PSS. Typical values of shunt index using this technique are less than 5% for normal dogs and greater than 90% for dogs with congenital PSS. This wide separation of values suggests that this is a particularly accurate diagnostic test.

**ASSESSMENT OF PROGNOSIS**

Although most dogs improve clinically after surgery to treat congenital PSS, some dogs have persistently high serum bile acid concentrations, and some have recurrent signs months or years after apparently successful surgery. There have been attempts to use scintigraphy to gain information that can serve as a basis for prognosis.

In a recent retrospective study of 126 dogs with PSS, there was no difference in preoperative SF between dogs with congenital and acquired PSS or between dogs with congenital PSS in different anatomic sites. Furthermore, there was no correlation between preoperative SF and clinicopathologic results, inoperative portal, or final outcome. Therefore, although it is a useful diagnostic test, calculation of SF does not help define the type of shunt or predict the outcome.

After surgery to treat congenital PSS, SF falls to less than 30% in most dogs. In a dog with a congenital PSS that is completely ligated, the postoperative SF will be in the normal range. When using the colonic method of scintigraphy to measure SF following shunt attenuation, the immediate postoperative SF may not be significantly different from the preoperative SF, yet the animal improves clinically. This discrepancy may reflect a lack of precision in SF determinations. There are various technical difficulties with using colonic portal scintigraphy, including a high degree of inter-operator variability, which makes it difficult to compare results from different dogs or repeated measurements on the same dog. Despite these difficulties, SF is often measured to monitor the progress of shunt occlusion. In dogs in which it is not possible to fully ligate the shunt (because portal pressures rise too high), attenuation may be achieved using a device called an Ameroid constrictor to gradually attenuate the lumen of the shunting vessel. In most dogs treated this way, SF is

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*Personal communication: Daniel GB, University of Tennessee, Knoxville, 2002.*
normal within 4 to 8 weeks. Dogs with persistently increased SF 60 days after surgery usually have developed acquired PSS (Figure 10).

REFERENCES

Figure 10—Operative portal venogram of a dog that developed multiple PSS as a result of portal hypertension following treatment of a congenital PSS using an ameroid constrictor.


### ARTICLE #4 CE TEST

The article you have read qualifies for 1.5 contact hours of Continuing Education Credit from the Auburn University College of Veterinary Medicine. *Choose the best answer* to each of the following questions; then mark your answers on the postage-paid envelope inserted in *Compendium*.

1. Old English sheepdogs and Australian cattle dogs are predisposed to which type of PSS?
   a. congenital extrahepatic
   b. congenital intrahepatic
   c. multiple acquired extrahepatic
   d. patent ductus venosus

2. Which condition is unlikely to result in portal hypertension?
   a. hepatic cirrhosis
   b. hepatic arterioportal fistula
   c. portal vein atresia
   d. patent ductus venosus

3. Which contrast radiographic procedure would not be suitable as a means of portal venography?
   a. operative mesenteric portography
   b. cranial mesenteric angiography
   c. celiac angiography
   d. percutaneous splenoportography

4. Which statement about the canine liver is correct?
   a. Radiographic evaluation of liver size is usually based on a subjective assessment.
   b. Linear dimensions of the liver are roughly proportional to its volume.
   c. Linear measurements of the liver are roughly proportional to body weight.
   d. all of the above

5. Which statement about ultrasonography of congenital PSS is correct?
   a. Ultrasonography is less than 50% accurate for diagnosing congenital PSS in dogs.
   b. Extrahepatic PSS is most readily visualized using a ventral approach.
   c. It is rarely possible to distinguish intrahepatic versus extrahepatic PSS ultrasonographically.
   d. Extrahepatic PSS is often visible when it joins the caudal vena cava between the right renal and hepatic veins.

6. Which abnormality is commonly observed during ultrasonography in dogs with congenital PSS?
   a. small kidneys
   b. urolithiasis
   c. pancreatic edema
   d. portal vein thrombosis

7. Scintigraphy following the administration of $^{99m}$Tc-pertechnetate enables examination of which hepatic function?
   a. reticuloendothelial cell function
   b. kinetics of bile flow
   c. portal blood flow
   d. hepatocyte metabolism

8. When performing scintigraphy by injection of $^{99m}$Tc-labeled macroaggregated albumin into a splenic vein, normal values for SF in dogs are usually less than ____%.
   a. 5
   b. 15
   c. 30
   d. 50

9. Preoperative measurement of SF in dogs with suspected PSS usually enables determination of
   a. intra- versus extrahepatic shunt location.
   b. congenital versus acquired PSS.
   c. likelihood of successful surgical treatment.
   d. presence or absence of PSS.

10. What is the most likely diagnosis in a dog with suspected hepatic insufficiency in which ultrasonography and scintigraphy reveal low-velocity hepatofugal flow in the portal vein and a SF of 50%?
   a. congenital intrahepatic PSS
   b. congenital extrahepatic PSS
   c. acquired extrahepatic PSS
   d. hepatic disease without significant PSS