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EMERGENCY AND CRITICAL CARE MEDICINE®

FROM THE PUBLISHER OF COMPENDIUM

PORTOSYSTEMIC SHUNTS AND PORTAL VENOUS HYPOPLASIA

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Portosystemic shunts (PSS) are vascular anomalies that can be either congenital or acquired. Congenital shunting most commonly occurs as a single vessel that provides direct vascular communication between the portal venous supply and the systemic circulation (cava or azygous veins), bypassing the liver. This commonly occurs as a single intra- or extrahepatic communication (80%). Acquired shunts most commonly occur secondary to chronic portal hypertension (20%) in which elevated portal pressures lead to the opening of fetal blood vessels. Before birth, these vessels divert portal blood away from the hepatic parenchyma into the systemic circulation. These vessels provide an alternative to handle an increase in the hydrostatic pressure load of the portal veins. Acquired shunts are usually multiple, tortuous, and extrahepatic. Hepatic cirrhosis is the most common cause of acquired extrahepatic shunts.

Normally, blood draining the stomach, intestine, spleen, and pancreas enters the portal vein and perfuses the liver through the sinusoidal network before entering the hepatic veins and, subsequently, the caudal vena cava. Portal blood contains nutrients, intestinal trophic hormones, bacterial products, intestinal-derived toxins, and pancreatic hormones. In fetuses, the liver has limited function to process these products, and a large shunting vessel (i.e., ductus venosus) bypasses the hepatic circulation. This vessel normally closes shortly after birth, establishing hepatic circulation. If the

ductus venosus remains patent, portosystemic shunting persists. When blood bypasses the liver, trophic factors (particularly insulin and glucagon) do not encourage hepatic growth, which results in poor hepatic development, hepatic atrophy, and hepatic failure.

Several types of congenital PSS are found in both dogs and cats, including patent ductus venosus, portal-caudal vena caval anastomosis, portal vein atresia with resultant multiple portal-caval anastomoses, portal azygous anastomosis, left gastric-caval or azygous anastomosis, hepatic arteriovenous fistula/malformation (HAVF/M), and microintrahepatic PSS (portal venous hypoplasia [PVH], formerly called microvascular dysplasia). Approximately 25% to 33% of congenital PSS in both dogs and cats are intrahepatic shunts (IHPSS). Single extrahepatic shunts (EHPSS), with a major solitary portal caval shunt being the most common, constitute 66% to 75% of congenital single PSS. Whereas most IHPSS are found in larger-breed dogs, most EHPSS are seen in smaller breeds.

The severity of clinical signs is related to the volume and origin of blood bypassing the liver, resulting in impairment of hepatic function (or hepatic failure), hepatic encephalopathy (HE), chronic gastrointestinal (GI) signs, lower urinary tract signs, coagulopathies, and retarded growth. Splenocaval shunts may have less severe clinical signs because splenic blood is not of GI origin. Clinical signs result from the accumulation of endogenous and exogenous toxins that are nor-

mally metabolized or eliminated by the liver (e.g., ammonia, gut-associated encephalopathic toxins, hormone metabolism, benzodiazepine-like substances, aromatic amino acids; Table 1) as well as the failure of normal hepatic metabolic function (e.g., gluconeogenesis, urea cycle, uric acid cycle). Dogs with IHPSS generally have a larger volume of blood flow through the shunt, which causes them to develop clinical signs at an earlier age than those with EHPSS.

PVH without a macrovascular shunt is a microscopic pathologic malformation of the hepatic microvasculature. It is characterized by small intrahepatic portal vessels, portal endothelial hyperplasia, portal vein dilation, random juvenile intralobular blood vessels, and central venous hypertrophy and fibrosis. These lesions may allow abnormal communication between the portal and systemic circulation at the microvascular level. This can occur as an isolated disease or in combination with macroscopic PSS. In one study, 58% of dogs and 87% of cats with PVH had concurrent congenital macroscopic PSS. Clinical signs in dogs with PVH can be similar to those associated with PSS but are often less severe, which offers a better long-term prognosis.

DIAGNOSTIC CRITERIA

Historical Information

Gender Predisposition

- **Dogs:** None.
- **Cats:** Males may be at greater risk than females.

Age Predisposition

- Range: 2 to 84 months; 64% of patients are diagnosed when they are younger than 1 year, 17% at 13 to 36 months, and 19% at older than 36 months.
- Median age for acquired multiple PSS: 3 years (range, 7 months to 7 years).
- Median age for congenital single PSS: 8.5 months (range, 2–84 months).
- PVH is often diagnosed later (up to 10 years of age).

Breed Predisposition

- **EHPSS (small breeds):** Yorkshire terriers, miniature schnauzers, Shih Tzus, pugs, Maltese, miniature dachshunds, bichons frises, silky terriers, Parson Russell terriers (formerly known as Jack Russell terriers), Skye terriers, Chihuahuas, toy poodles.
- **IHPSS (larger breeds):** Labrador retrievers, Irish wolfhounds, golden retrievers, Rottweilers, German shepherds, basset hounds, Australian cattle dogs, English setters, Siberian huskies, Dalmatians.
- **PVH:** Cairn terriers and Yorkshire terriers are overrepresented.

Owner Observations

- Lethargy (41%–100%).

KEY TO COSTS

§ indicates relative costs of any diagnostic and treatment regimens listed.

- § costs less than \$250
- §§ costs between \$250 and \$500
- §§§ costs between \$500 and \$1,000
- §§§§ costs more than \$1,000

Editorial Mission:

To provide busy practitioners with concise, peer-reviewed recommendations on current treatment standards drawn from published veterinary medical literature.

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TABLE 1
Toxins Implicated in Hepatic Encephalopathy

Toxin	Suggested Mechanisms
Ammonia	Increases brain tryptophan and glutamine Decreases ATP availability Increases excitability Increases glycolysis Brain edema Decreases microsomal Na ⁺ /K ⁺ -ATPase in the brain
Decreased α-ketoglutarate	Diversion from Krebs cycle for ammonia detoxification Decreases ATP availability
Glutamine	Alters BBB amino acid transport
Aromatic amino acids	Decrease dopamine neurotransmitter synthesis Alter neuroreceptors Increase production of false neurotransmitters
Short-chain fatty acids	Decrease microsomal Na, K-ATPase in the brain Uncouple oxidative phosphorylation; impair oxygen utilization; and displace tryptophan from albumin, increasing free tryptophan
False neurotransmitters	
Tyrosine → Octopamine	Impairs norepinephrine action
Phenylalanine → Phenylethylamine	Impairs norepinephrine action
Methionine → Mercaptans	Synergistic with ammonia and short-chain fatty acids Decrease ammonia detoxification in the brain urea cycle GI tract derived (feter hepaticus, which is breath odor associated with hepatic encephalopathy) Decrease microsomal Na ⁺ /K ⁺ -ATPase
Tryptophan	Directly neurotoxic Increases serotonin neuroinhibition
Phenol (from phenylalanine and tyrosine)	Synergistic with other toxins Decreases cellular enzymes Neurotoxic and hepatotoxic
Bile acids	Membranocytolytic effects alter cell membrane permeability BBB more permeable to other hepatic encephalopathy toxins Impaired cellular metabolism because of cytotoxicity
GABA	Neural inhibition: Hyperpolarizes neuronal membrane Increases BBB permeability to GABA
Endogenous benzodiazepines	Neural inhibition: Hyperpolarize neuronal membrane

BBB = blood-brain barrier; GABA = γ-aminobutyric acid.

- Incoordination, head pressing, circling, disorientation, pacing, behavior changes, depression, dementia, stupor (41%–90%).
- Failure to thrive or gain weight.
- Polyuria, polydipsia.
- Hematuria, pollakiuria, stranguria, dysuria (20%–53%).
- Seizures (16%).
- Weight loss (11%).
- Vomiting (5%), intermittent anorexia, diarrhea.
- Blindness (1.5%).
- Exacerbation of clinical signs after feeding.
- Pica.
- In cats, ptialism is the most common sign, followed by central nervous system and GI dysfunction.

Other Historical Considerations/Predispositions

- Runt of the litter.
- Waxing and waning behavioral changes associated with eating.
- History of poor anesthesia tolerance.

Physical Examination Findings

- Poor body condition; small stature.
- Lethargy (puppies).
- Neurologic dysfunction: Ataxia, behavioral changes, aggression, pacing, circling, head pressing, stargazing, blindness, tremors, seizures, stupor, coma.
- Poor, unkempt haircoat.
- Melena or hematemesis.

CHECKPOINTS

A recent study of dogs with PVH alone versus dogs with PVH and macrovascular PSS revealed that the former were older and had higher values for mean corpuscular volume (MCV), total serum protein, albumin, creatinine, cholesterol, BUN, and blood glucose and had lower paired serum bile acids.

Treatment of PVH is supportive because there is no macroscopic shunt to attenuate. Many dogs remain asymptomatic with dietary therapy alone, although the prognosis is variable.

- Renomegaly.
- Copper-colored iris (non-Oriental-breed cats).
- Abdominal effusion can be detected in dogs with hepatic AVF.

Laboratory Findings

- Elevated paired preprandial and 2-hour postprandial bile acids (nearly 100% sensitivity). \$
- Abnormal ammonia tolerance test result (nearly 100% sensitivity). Plasma ammonia should be measured before and after ammonium chloride administration (0.1 g/kg) as a 5% (per rectum) or 10% (oral) solution. Samples must be analyzed within 30 minutes. This test is contraindicated in animals with signs of HE. \$
- 12-hour fasting hyperammonemia (80%–87% sensitivity); 6-hour postprandial hyperammonemia (90% sensitivity). \$
- Complete blood count \$
 - Nonregenerative microcytic anemia.
 - Target cells (dogs); poikilocytes (cats).
- Serum biochemical profile \$
 - Normal or mildly increased liver enzyme activities despite hepatic failure.
 - Decreased blood urea nitrogen (BUN; 70%).
 - Hypoalbuminemia (50%).
 - Fasting normoglycemia or hypoglycemia.
 - Hypocholesterolemia.
- Urinalysis \$
 - Ammonium biurate crystalluria (33%–50%).
 - Decreased urine specific gravity (<1.025; hyposthenuria, isosthenuria, hypersthenuria).
 - Coagulopathy: Increased active partial thromboplastin time and prothrombin time; hypofibrinogenemia. \$

Other Diagnostic Findings

- Ammonium acid urate stones or uric acid stones.

- Imaging studies:
 - **Abdominal radiography:** Microhepatica, renomegaly, faintly opaque uroliths; loss of abdominal detail in animals with AVF and concurrent ascites. \$
 - **Abdominal ultrasonography:** Can often distinguish between intra- and extrahepatic shunt vessels; it is difficult to find multiple extrahepatic shunt vessels using ultrasonography; allows identification of urinary calculi (sensitivity for EHPSS, ≤81%, specificity, 67%; sensitivity for IHPSS, ≤100%; 93% in cats with IHPSS or EHPSS). \$\$
 - **Hepatic blood flow imaging** (mesenteric portography, percutaneous splenoportography, cranial mesenteric arterial portography): Gold standard for identifying PSS. \$\$-\$\$\$
 - **Nuclear transcolonic portal scintigraphy:** ^{99m}Techetium pertechnetate can quantify relative shunt blood flow. \$\$
 - **Computed tomography (CT) with angiography:** Ideal for localization of IHPSS and HAVF/M. \$\$\$
- Exploratory laparotomy for identification of shunt vessels. \$\$\$
- In animals with AVF, abdominal fluid analysis may reveal pure transudate. \$

Summary of Diagnostic Criteria

- Signs of GI disease and HE: Ataxia, behavioral changes, aggression, pacing, circling, head pressing, stargazing, blindness, tremors, seizures, stupor, coma.
- Lethargy; poor body condition.
- Elevated paired serum bile acids.
- Hyperammonemia; abnormal ammonia tolerance test result.
- Abnormal liver function parameters (hypoalbuminemia, hypoglycemia, low BUN, hypocholesterolemia) with microcytic anemia.
- Ammonium biurate crystalluria.
- Evidence of microhepatica and a shunt vessel seen on abdominal imaging.
- Direct evidence of a single shunt or intrahepatic AVF found on ultrasonography, portal venography, or CT angiography.

Diagnostic Differentials

- **PVH versus PSS:** Portography, CT angiography, liver biopsy. \$\$\$
- **Protein-losing enteropathy:** Paired serum bile acids, fecal parasites (\$); GI biopsies (\$\$).
- **Primary neurologic dysfunction:** Paired serum bile acids, central nervous system imaging (CT or magnetic resonance imaging). \$\$

TABLE 2
Supportive Therapy for Patients with PSS/PVH

Condition or Goal	Therapy
Emergent Care for Hepatic Encephalopathy	
Bacterial translocation or decreasing ammonia absorption	Cleansing enemas with warm water or 30% lactulose solution at 5–15 ml/kg total dose Antibiotics: Metronidazole: 7.5 mg/kg IV or PO bid Ampicillin: 20 mg/kg IV tid Neomycin: 22 mg/kg PO bid (avoid if there is any evidence of intestinal bleeding or ulcerations)
GI ulceration	Antacids: Famotidine: 0.5–1.0 mg/kg/day IV or PO Omeprazole: 0.5–1.0 mg/kg sid or bid PO Misoprostol: 2–3 µg/kg bid to tid PO Protectant: Sucralfate: 1 g/25 kg PO tid
Coagulopathy	Correct coagulopathy Fresh-frozen plasma (10–15 ml/kg over 2–3 hr) Vitamin K ₁ : 1.5–2.0 mg/kg SC or IM q12h for three doses; then once daily
Seizures	Avoid benzodiazepines; consider IV phenobarbital (4 mg/kg IV) or potassium or sodium bromide loading
Additional Supportive Therapy	
Cerebral edema	Mannitol (0.25–1.0 g/kg IV over 20–30 min)
Hepatoprotective therapy	S-adenosylmethionine (SAME): 17–22 mg/kg/day PO Ursodeoxycholic acid: 10–15 mg/kg/day Vitamin E: 15 IU/kg/day Milk thistle: 8–20 mg/kg divided tid L-carnitine: 250–500 mg/day (cats) Vitamin B complex: 1 ml/L of IV fluids
Nutritional support	Moderate protein restriction: 18%–22% for dogs and 30%–35% for cats; dairy or vegetable proteins Vitamin B supplementation Multivitamin supplementation

- **Atypical hypoadrenocorticism:** Corticotropin stimulation testing and paired serum bile acid testing. \$
- **Protein-losing nephropathy:** Urine protein:creatinine ratio. \$
- **Hyperbilirubinemia:** Excludes PSS, PVH, and AVF as causes of disease because they are not cholestatic liver diseases. Chronic hepatitis, idiopathic noncirrhotic portal hypertension, fibrosing hepatitis, cirrhosis, and cholangitis or cholangiohepatitis should be considered. A liver biopsy is needed to differentiate PVH from the other differential diagnoses.

TREATMENT RECOMMENDATIONS

The durations of medications are variable depending on the ability to correct the shunting vessel(s). For dogs for which surgical correction is not possible, lifelong medical management may be necessary.

Initial Treatment

Acute Hepatic Encephalopathy/ Fulminant Hepatic Failure (Table 2)

- Nothing should be given PO unless the patient is alert and aware.
- **Replacement IV fluid therapy** (0.9% NaCl or Normosol-R) at a rate based on estimated degree of dehydration (~90 ml/kg/day); caution should be taken to avoid hypokalemia.
- **Cleansing enemas:** Warm-water, lubricating, lactulose-containing enemas should be used until ammonia is within reference limits. Retention enemas with lactulose are also helpful for severe HE.
 - 5–15 ml/kg of warm water and lubrication.
 - Lactulose can be added to this combination.

Antibiotic therapy \$

- Metronidazole: 7.5 mg/kg IV bid.
- Ampicillin: 20 mg/kg IV tid.

ON THE NEWS FRONT

- The pathogenesis of HE is incompletely understood in both veterinary and human medicine. HE occurs when more than 70% of hepatic function is lost. Multiple aspects of central nervous system metabolism have been implicated in the pathophysiology of HE, and more than 20 compounds can be found in increased concentrations in the circulation when liver function is impaired (Table 1). Liver failure may result in a form of HE that leads to cerebral edema, increased intracranial pressure, and herniation of the brain. Edema is described in up to 80% of humans with the condition, with 33% of them developing fatal herniation. It is theorized that combinations of synergistic events and complex metabolic derangements occur in patients with hepatic insufficiency and are responsible for the variable neurologic signs seen. Contributing factors include systemic toxins (Table 1), metabolic derangements (hypoglycemia, dehydration, azotemia, hypokalemia, alkalemia), a high-protein diet, GI ulceration, blood transfusion, constipation, and drug therapy (sedatives, analgesics, benzodiazepines, antihistamines). These factors, in addition to an altered permeability of the blood–brain barrier, impair cerebral function in variable ways.
- GABA and its receptors are implicated in the pathogenesis of HE. The benzodiazepine antagonist flumazenil has been shown to be of benefit in humans with HE-induced comas. Evaluation in veterinary patients has not yet been done.
- The diet should be readily digestible, contain a protein source of high biologic value (enough to meet the animal's need without encouraging HE), supply enough essential fatty acids, maintain palatability, and meet the minimum requirements for vitamins and minerals. Low-protein diets should be avoided unless HE is noted. Milk and vegetable proteins are lower in aromatic amino acids and higher in branched-chain amino acids (valine, leucine, isoleucine) than animal proteins and are considered less likely to potentiate HE. In patients with fulminant hepatic failure, total or partial parenteral nutrition should be considered if enteral intake cannot be tolerated.
- Substitution of hepatocytes in various forms of artificial liver support has been promoted over the past 10 years in human medicine. A multicenter, randomized trial of a bioartificial liver showed questionable benefit in overall outcome over traditional therapy while awaiting transplantation or hepatocyte recovery, although more advanced equipment is showing great promise. Research is still avid in this area and may be something seen in future veterinary medicine.
- Based on the frequency of cerebral edema with associated herniation in humans, the use of mannitol in treating patients with HE should also be considered.
- Dogs with ameroid ring constrictor placement for EHPSS have reported clinical outcomes classified as excellent (80%), good (14%), and poor (6%).

— Neomycin: 22 mg/kg PO bid–tid. Do not use in patients with evidence of GI bleeding or inflammation; neomycin can be severely nephrotoxic if it is absorbed systemically.

- **± Benzodiazepine receptor inhibition** (anecdotal evidence in animals): Flumazenil, 0.02 mg/kg IV to effect. This is based on the suggestion that endogenous benzodiazepines contribute to HE.
- **Mannitol** for cerebral edema in patients with severe HE or to control postseizure activity: 0.25–1.0 g/kg IV bolus over 15 minutes diluted 1:1 with saline; then 1 mg/kg/min constant-rate infusion (CRI) if necessary.

To Control Seizures

- **Low-dose midazolam:** 0.1–0.2 mg/kg IV as needed. This benzodiazepine is preferred over diazepam

because there is no propylene glycol–carrying agent, although diazepam is considered appropriate in low doses (0.1–0.2 mg/kg IV or CRI). \$

- **Phenobarbital:** \$
 - Loading dose: 4 mg/kg IV q6h for 18–24 hr.
 - Maintenance dose: 2 mg/kg bid PO or IV.
- **Potassium bromide:** Should be used with caution in cats because it may exacerbate feline bronchial spasm. \$
 - Loading dose: 400–600 mg/kg/day divided over 1–5 days PO with food; can be given per rectum if patient is unable to take oral medications.
 - Initial maintenance dose: 20–30 mg/kg/day PO.
- **Sodium bromide** can also be used, given IV in cases of severe HE for loading. \$

- **Propofol** for refractory seizure activity or patients with status seizure activity: 3–6 mg/kg IV followed by a CRI of 8–12 mg/kg/hr; patients must be closely monitored for hypoventilation and may require mechanical ventilatory support. **\$\$**

To Correct Coagulopathies Before Surgery or Liver Biopsy

- **Vitamin K₁**: 1.5–2.0 mg/kg SC or IM q12h for three doses; then q24–48h. **\$**
- **Fresh-frozen plasma**: 10–1.5 ml/kg IV over 2–4 hr until coagulation parameters normalize. **\$\$**

To Treat Severe Anemia

- Severe anemia is packed cell volume (PCV) <20%.
- **Packed erythrocyte transfusion**: 10 ml/kg IV over 2–4 hr.
- Blood accumulates ammonia with storage, so recently stored cells are better.

Medical Management

Medical management is indicated to control the clinical signs of HE in stable patients. This is the mainstay of therapy for multiple acquired PSS and PVH and is also indicated for preoperative stabilization before anesthesia.

- **Lactulose**: 0.5–1.0 ml/kg PO tid–qid. **\$**
 - Modifies (acidifies) colonic pH, leading to ion trapping; decreases intestinal transit time and has an antiendotoxin effect.
 - Administered to effect with the goal of two to three soft stools per day.
 - May monitor stool pH.
- **Metronidazole** (7.5 mg/kg PO bid), plus amoxicillin/ampicillin (20 mg/kg PO tid) with or without neomycin (22 mg/kg PO bid). **\$**
 - Nephrotoxicity and ototoxicity are rare side effects.
 - These agents are used to modify enteric flora that produce the toxins implicated in the genesis of signs of HE.
 - Urease-producing bacteria hydrolyze intestinal urea to produce ammonia and should be targeted in the antibiotic regimen.
- **Nutritional management**: A readily digestible diet with limited to moderate protein (e.g., Hill's Prescription Diet I/d, which is a balanced diet for growing puppies, or k/d; homemade high-quality, low-protein food) is indicated to reduce dietary ammonia and aromatic amino acids, supply enough essential fatty acids, maintain palatability, and meet the minimum requirements for vitamins and minerals. Low-protein diets should be avoided unless HE is noted. **\$**

- **Gastric acid blockade** for GI ulceration: **\$**
 - Omeprazole: 0.5–1.0 mg/kg q12–24h.
 - Famotidine: 0.5–1.0 mg/kg q12–24h.

Surgical Management

Surgery is needed to redirect shunting blood to the liver, reverse hepatic atrophy, and resolve clinical signs. A medically stabilized patient has the best chance of successful surgical recovery.

Extrahepatic Shunts **\$\$\$**

- **Ameroid constrictor placement or cellophane banding during abdominal exploratory surgery**: An ameroid constrictor or sterile cellophane material results in a gradual and complete closure of the shunt as a result of vessel irritation and subsequent thrombosis. Some evidence suggests that closure can occur as early as 3 days after placement with ameroid constrictors. The hygroscopic casein expands when placed in fluid (peritoneal fluid); expansion occurs rapidly over the first 14 days and then more slowly over the next 2 months. Initially, the device should not constrict the shunt by more than 25% of its original diameter to avoid portal hypertension.
- **Vessel suture ligation** (partial or complete): Baseline portal pressures are obtained, and a ligature is then manipulated around the shunt to temporarily occlude the anomalous vessel. The splanchnic viscera are inspected for signs of portal hypertension (congestion, cyanosis, hypermotility). Portal hypertension is potentially avoided by keeping the postligation pressures within 7 to 10 cm H₂O (6–8 mm Hg) above baseline and total portal pressures below 20 to 22 cm H₂O. Central venous pressure (CVP) should not decrease more than 1 cm H₂O. Cellophane banding is reported to be the most consistent progressive attenuation in dogs. **\$\$\$**
- **Complications**: Surgical mortality is 7% to 15% after ameroid constrictor placement and up to 29% after suture ligation. A good to excellent outcome is achieved when complete shunt closure is achieved. Outcome is guarded (41% complication rate) when only partial ligation is achieved. A 17% long-term complication rate related to the development of multiple acquired shunts after ameroid constrictor placement has been reported.

Intrahepatic Shunts **\$\$\$**

Many surgical techniques are available for attenuating IHPSS, which is far more challenging than EHPSS fixation. In one study, surgical mortality was 18% immediately after surgery for partial or complete shunt ligation; 13% of patients were euthanized because of uncontrollable HE after surgery, and 7% required another surgery. Overall mortality ranges from 18% to 67%. The various procedures described include:

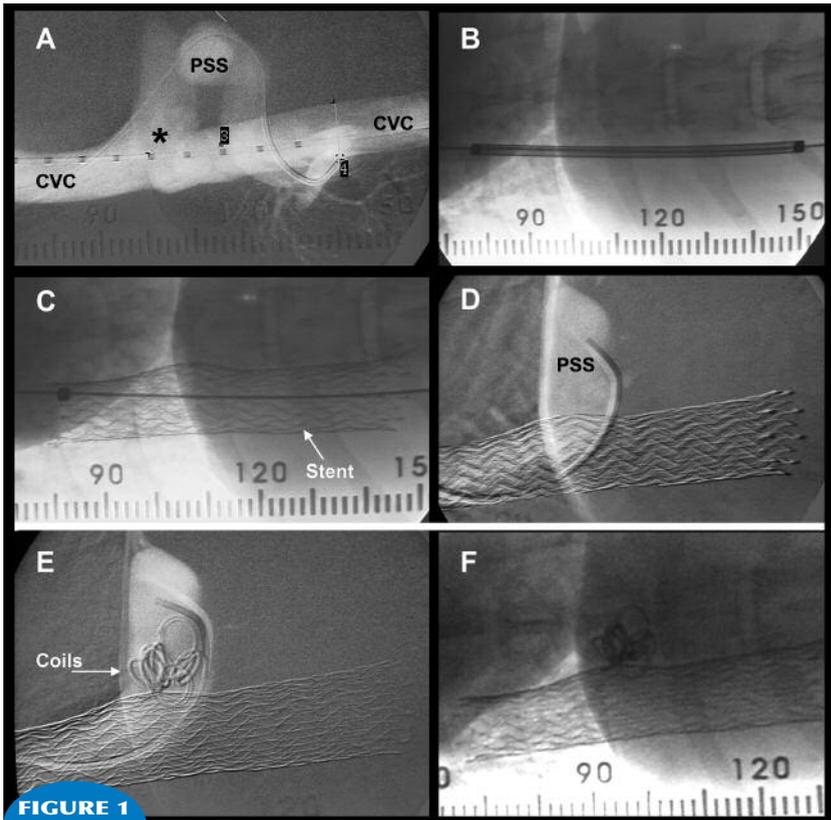


FIGURE 1

A study of a dog with a left divisional intrahepatic portosystemic shunt (IHPSS) during PTCE. Percutaneous venous access is obtained into the jugular vein. Under fluoroscopic guidance, a guidewire is passed down the jugular vein into the cranial vena cava through the right atrium and into the caudal vena cava. **A.** Digital subtraction angiography (DSA) is performed during fluoroscopy. Contrast is present within the caudal vena cava (CVC) and portosystemic shunting vessel (PSS). The mouth of the shunt is identified (*). A marker catheter (3) allows adjustment for radiographic magnification, and the vena cava is measured (4) for appropriate selection of stent size. **B.** The stent delivery system is advanced over a guidewire and positioned to cross the mouth of the shunt that was previously identified. **C.** The stent is then deployed in the selected location. **D.** The mouth of the shunt is again selected with a catheter, and another DSA is performed to confirm the stent location across the shunt opening. **E.** Through the catheter, thrombogenic coils are placed into the shunting vessel while portal pressures are measured intermittently. **F.** Following sufficient increase in portal pressures, the catheter is removed and the stent and coils remain in place. The procedure allows a slow attenuation of the shunting vessel while the thrombogenic coils allow a clot to form and occlude the blood flow.

- Cellophane banding or suture material.
- Complete or partial ligation.
- Ultrasonography-guided placement of suture around the shunt (within the hepatic parenchyma).
- Intrahepatic shunt localization and attenuation of the shunt by ultrasonic aspirator.
- Portal venotomy and transportal attenuation.
- Creation of an extrahepatic portocaval anastomosis with complete intrahepatic shunt ligation.

- Placement of a hydraulic occluder for slowed attenuation.

Hepatic Arteriovenous Fistula \$\$\$

- Hepatic lobectomy of the involved liver lobe.
- Percutaneous arterial glue embolization.

Minimally Invasive Therapeutic Alternatives for Vascular Shunting Percutaneous Transjugular Coil Embolization

IHPSS occurs most commonly in large-breed dogs and is associated with relatively high rates of surgical morbidity and mortality. Percutaneous transjugular coil embolization (PTCE) (Figure 1) has significantly reduced perioperative complication rates compared with reported traditional surgical procedures and has a similar or lower mortality rate.

PTCE is a minimally invasive procedure that produces very little postoperative discomfort and minimal morbidity. The most common cause of postoperative morbidity (approximately 20%) is from GI ulceration, which has been avoided by the long-term administration of omeprazole to all patients. The mortality rate for PTCE is less than 5% during surgery; long-term mortality after surgery is less than 15%.

Very few institutions are performing this procedure (see Resource List on page 10).

Hepatic Arteriovenous Fistula/ Malformation Glue Embolization

HAVMs are rare vascular anomalies that can be found in the liver of young dogs (Figure 2). This condition involves multiple arterial

communications to the portal vein. These communications are usually from the hepatic artery but have been seen to also involve other arteries such as the gastroduodenal artery (GDA). Surgical resection or ligation of these communications is usually recommended; however, sometimes they are extensive, so surgery is not an option. Because of high-pressure arterial blood shunting to the portal vein, severe portal hypertension occurs, resulting in multiple extrahepatic shunts to help decompress the portal vein. In

about 75% of cases, ascites is present from the increased hydrostatic pressure. Diagnosis is often made on abdominal ultrasonography, CT angiography, or exploratory surgery. If the mass of arterial vessels is not resectable or the main vessel is unable to be appropriately ligated surgically, a novel approach has been performed in 10 cases to date.

Alternative/Optional Treatments/Therapy

- Medical management (Table 2) is an option for patients with PSS and PVH. Dogs with IHPSS treated with medical management alone have a mean survival time of approximately 10 months. \$
- If urate uroliths are found in the bladder at the time of surgery, a cystotomy or lithotripsy can be considered at the time of PSS fixation or during a subsequent anesthetic event. \$\$\$\$

Supportive Treatment

- Blood glucose should be monitored; supplemental IV dextrose may be needed for patients being fasted for anesthesia or that are not eating after surgery. \$
- As a result of hypoalbuminemia, low colloid oncotic pressures are expected, and colloidal support may be necessary (hetastarch, 20 ml/kg/day). \$
- Hepatoprotective therapy (Table 2) is optional for animals with PSS or PVH, although little evidence-based medicine supports such therapy for these particular conditions. \$
- If partial ligation was used to attenuate the shunt and clinical signs are still evident 2 to 4 months after surgery, a second surgery for complete ligation may be necessary. \$\$\$\$
- Antacid therapy (omeprazole, 0.5–1.0 mg/kg sid–bid) to prevent GI ulceration: 23% of dogs with IHPSS have a history of GI bleeding (melena, hematemesis). \$
- Famotidine (0.5 mg/kg bid PO) or ranitidine (2.2 mg/kg bid PO). \$

Patient Monitoring

- 12-hour fasting ammonia level.
- Paired serum bile acid is tested after intervention

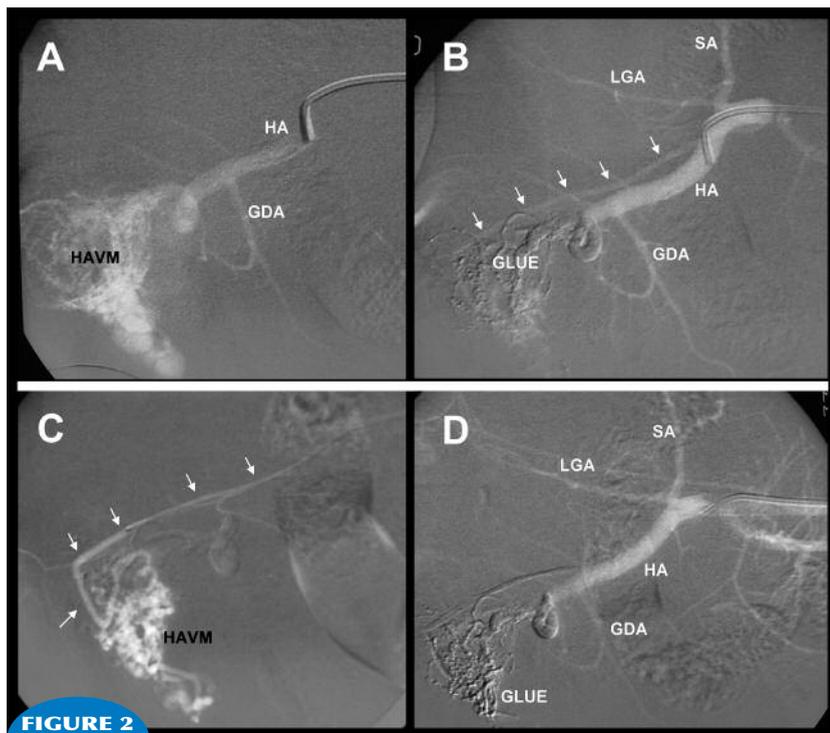


FIGURE 2 Angiographic study of a dog with HAVM. **A.** A catheter is advanced from the femoral artery to the aorta and celiac artery and is seen here in the hepatic artery (HA). Contrast medium is injected under fluoroscopic guidance. The HAVM is identified just beyond the gastroduodenal artery (GDA). **B.** DSA is performed after cyanoacrylate glue is injected into the malformation, which polymerizes and occludes the small communications of the malformation. The splenic artery (SA) and left gastric artery (LGA) are visualized because of the increased arterial flow after the shunt is partially occluded. A previously unidentified feeding branch of the HAVM is now visible (*arrows*) because of the reduced flow through the HAVM. **C.** A microcatheter is advanced into the small vessel feeding the HAVM (*arrows*), and DSA is performed. **D.** Glue is injected into the small vessel identified, and a repeat celiac arteriogram is performed, demonstrating increased filling of the HA, SA, LGA, and GDA with reduced filling of the HAVM after glue embolization.

and is usually rechecked at 3 months to monitor functional improvement.

- Liver function parameters: Albumin, glucose, cholesterol, BUN.
- PCV or MCV.
- Clinical neurologic signs.
- GI signs: Diarrhea, vomiting, weight loss, melena, abdominal effusion.
- Nuclear scintigraphy, CT, or portal angiography should be repeated at 3 to 6 months after surgery to evaluate for complete shunt closure. If there is still evidence of incomplete closure and the patient is symptomatic, a second surgery for complete ligation or the addition of coils into the shunting vessel may be necessary.

RESOURCE LIST

Practices performing these minimally invasive procedures include (but are not limited to):

IHPSS PTCE Procedure

- Matthew J. Ryan Veterinary Hospital of the University of Pennsylvania
- Michigan State University
- The Ohio State University
- The Justus-Liebig University, Geissen, Germany
- Texas A&M University
- Tufts University
- Veterinary Specialty Center, Buffalo Grove, IL
- Veterinary Specialty Hospital of San Diego, CA

AVM Embolization

- Matthew J. Ryan Veterinary Hospital of the University of Pennsylvania
- Veterinary Specialty Hospital of San Diego, CA

Home Management

- Antacid therapy (particularly for patients with IHPSS).
- Nutritional support.
- Lactulose.
- Antibiotic therapy.
- Antiseizure medication if necessary.

Milestones/Recovery Time Frames

- Improving liver functional parameters.
- Improved results on bile acid testing.
- Resolution of neurologic signs.
- Weight gain.

Treatment Contraindications

- Diazepam should be avoided in treating neurologic disease and as a premedication before anesthesia because of the propylene glycol-carrying agent.
- Drugs metabolized by the liver should be avoided.
- Parenteral (SC or IM) vitamin K₁ should be used.

PROGNOSIS

- The prognosis for medical management alone is guarded to poor for patients with PSS because hepatic atrophy is progressive and clinical signs eventually worsen. In one study, most dogs with IHPSS were euthanized because of the inability to control clinical signs within the first 10 months; 33% survived more than 36 months with medical management alone (both IHPSS and EHPSS).
- Acute surgical complications include portal hypertension, portal vein thrombosis, hemorrhage at the

portal vascular catheterization site or hepatic biopsy site, acute pancreatitis, intussusception, and prolonged anesthesia recovery.

- Chronic surgical complications include multiple acquired PSS from chronic portal hypertension and ascites.

Favorable Criteria

- Animals that have a single extrahepatic PSS that do not present with signs of HE may do better after surgery.
- Complete ligation of a single EHPSS or IHPSS without the development of an unacceptable level of portal hypertension at surgery is a positive prognostic sign.
- Age does not appear to increase the risk for early postoperative mortality, as was previously thought.
- Low portal pressures, low leukocyte counts, and normal albumin levels are positive prognostic indicators.
- Predictive factors for excellent long-term clinical outcome include high preoperative plasma albumin concentration, low preoperative leukocytosis, low portal pressure after complete occlusion, absence of postoperative seizures, and absence of continued shunting.

Unfavorable Criteria

- Clinical signs of portal hypertension include painful abdomen, hemorrhagic diarrhea, and hypovolemic or endotoxic shock.
- Melena, GI ulceration.
- Treatment of postoperative seizures is often unsuccessful. Propofol has been used successfully to manage seizure activity after treatment in a small number of dogs and cats.
- Vascular anomalies that cannot be corrected surgically include portal venous atresia, AVF in multiple liver lobes, and acquired multiple EHPSS.
- Postligation portal pressure >20 cm H₂O, increase of postligation portal pressure >10 cm H₂O above baseline, decrease in CVP >1 cm H₂O, decrease in mean arterial pressure >10 mm Hg, evidence of splanchnic visceral cyanosis, and intestinal hypermotility.
- Older age at onset of signs has been associated with longer survival times.
- Lower BUN at the time of diagnosis has been associated with shorter survival times.
- Development of uncontrollable neurologic deficits such as seizures, circling, pacing, ataxia, incoordination.
- Development of portal vein thrombosis within 3 to 4 days after surgery: Lethargy, depression, ascites, abdominal pain, bloody diarrhea.
- The results of surgical ligation of EHPSS in cats seem to be worse than in dogs, with only approximately 50% to 60% of cats having a favorable outcome.

- The prognosis for patients with IHPSS is more guarded because of the technical difficulties of the surgical correction and an inability to completely attenuate the shunt without the development of portal hypertension. Since the development of the PTCE procedure, the prognosis is improving.
- Dogs with EHPSS undergoing ameroid constrictor placement have been documented to have predictive factors for postoperative death, including a high preoperative leukocyte count and postoperative complications.
- Predictive factors reported for persistent shunting include low preoperative plasma albumin concentration, high portal pressure after complete occlusion, and high portal pressure difference.
- Recent evidence suggests that dogs with EHPSS have a similar outcome as younger dogs after ameroid ring placement.

RECOMMENDED READING

- Christiansen JS, Hottinger HA: Hepatic microvascular dysplasia in dogs: A retrospective study of 24 cases (1987–1995). *JAAHA* 36:385–389, 2000.
- Howe LM, Booth HW: Diagnosing and treating portosystemic shunts in dogs and cats. *Vet Med* 97:448–459, 2002.
- Schneider M, Plassmann M, Rauber K: Coil embolization of portosystemic shunts in comparison with conventional therapies. *Proc 15th ECVIM*, 2005.
- Tams TR: Diseases of the liver and hepatobiliary system, in Tams TR (ed): *Handbook of Small Animal Gastroenterology*, ed 2. St. Louis, Elsevier Science, 2003, pp 330–335.
- Watson PJ, Herrtage ME: Medical management of congenital portosystemic shunts in 27 dogs: A retrospective study. *J Small Anim Pract* 39:62–68, 1998.
- Weisse C, Solomon J: Percutaneous transjugular coil embolization for intrahepatic portosystemic shunts in 37 dogs. *Proc ACVS*, 2005.
- Winkler JJ, Bohling MW, Tillson DM, et al: Portosystemic shunts: Diagnosis, prognosis and treatment of 64 cases (1993–2001). *JAAHA* 39:169–185, 2003.