Portosystemic Shunts in Canine Patients

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Portosystemic shunts (PSS) are the most common canine portovascular abnormality [13]. A PSS is an anomalous vessel that allows normal portal blood draining from the stomach, intestines, pancreas and spleen to pass directly into the systemic circulation, bypassing the liver [9]. Normally, blood from stomach, intestines, pancreas and spleen flows into the portal vein, which then enters the liver [5]. This blood contains nutrients, bile acids, ammonia, glucose, toxins, and bacterial products that are absorbed from the intestines [8]. These substances are metabolized or detoxified by the liver allowing blood to pass into systemic circulation without causing dangerous accumulation of them [4, 6, 9]. With PSS, portal blood bypasses the liver and glucose and other nutrients are not available to the liver resulting in poor hepatic development, reduced liver function, and presentation of clinical sings [6]. Presentation of clinical signs often prompts owners to seek veterinary attention for their dog [9, 13].

Suspect PSS patients that present to the veterinarian may have a characteristic signalment, history, and various clinical signs [9, 13]. While there is no sex predilection for PSS, certain breeds are at increased risk for having this vascular anomaly [14]. Dogs presenting with congenital PSS are significantly more likely to be younger (less than 2-3 years) and weigh less than dogs with acquired PSS [1, 9]. Purebred dogs and the following small breed dogs are at increased risk of having a congenital extrahepatic PSS (CEPPS): Cairn Terriers, Yorkshire Terriers, West Highland White Terriers, Maltese, Havanese, Silky Terrier, Miniature Schnauzer, Poodle, Lhasa, Apso, Bichon Frise, Jack Russell Terrier, Shih Tzu, and Pekingese [6, 9, 13, 14]. Intrahepatic shunts are more likely to be found in large breed dogs such as the Irish Wolfhound, German Shepard, Golden Retriever, Doberman Pinscher, and Labrador Retriever [9, 13]. A genetic predisposition for PSS has been documented in Maltese dogs and Irish Wolfhounds [6]. PSS patients may not always belong to the associated age group or breed and clinical signs vary.

Clinical signs of PSS are varied but primarily present as gastrointestinal, urinary, and neurologic signs [6]. Dogs with acquired PSS (APSS) are significantly more likely to present with diarrhea, weight loss, and have a poor body condition (BCS less than 4 out of 9) than dogs with CPSS [1]. Additionally, ascites is significantly more common in dogs with APSS due to the portal hypertension [1, 9]. Typically, CEPSS patients present to the veterinarian for failure to grow and thrive, weight loss, vomiting, anorexia, pica, urinary signs, and neurologic abnormalities [1, 6, 9, 16]. Urinary signs include polyuria, polydipsia, pollakiuria, and stranguria; these signs are attributed to formation of ammonium biurate crystals in the kidneys and bladder. Ammonium biurate crystals form due to decreased urea production, increased ammonia excretion, and decreased uric acid metabolism [6, 16]. Dogs with CEPSS are significantly more likely to have neurologic signs than dogs with APSS [1]. Neurologic abnormalities may include mild changes such as depression, lethargy, ataxia, and weakness or severe changes such as central blindness, head pressing, circling, pacing, staring into walls or corners, seizures, or coma [1, 6, 9]. Neurologic signs are consistent with hepatic encephalopathy and are most commonly associated with increased circulatory levels of ammonia and bacterial products [1, 2, 18]. These clinical signs are helpful in determining if a presenting patient has an APSS or CPSS and in evaluating a patient's disease severity [1, 9]. Understanding the pathophysiology of PSS can help further explain why these clinical signs exist [4, 6].

Portosystemic shunts are a common canine vascular anomaly and develop in utero or at birth or are acquired in response to abnormal hemodynamics [9]. PSS present as congenital or acquired and as extrahepatic or intrahepatic [9]. An extrahepatic PSS is characterized as a vascular anomaly outside of the hepatic parenchyma that connects the portal vein to the azygos vein, left gastric vein to the caudal vena cava, splenic vein to the caudal vena cava, left gastric, cranial

mesenteric, caudal mesenteric, gastroduodenal vein to the caudal vena cava, or most commonly the portal vein to the vena cava (portocaval) [9, 19]. Dogs with splenocaval shunts and shunts inserting in the caudal vena cava and caudal to the liver are significantly more likely to have clinical signs [12]. Sixty-three percent of single shunts in dogs are congenital [9]. CEPSS form due to embryologic developmental errors [6]. Congenital intrahepatic PSS form when the fetal structure, the ductus venosus, fails to close by 3-10 days of age [6, 9]. In the fetus, the ductus venosus carries oxygenated maternal blood from the placental to fetal circulation bypassing the hepatic circulation as a protective mechanism [4, 6]. Acquired extrahepatic PSS (AEPPS) presents in the form of multiple shunts within a patient [9]. AEPSS form due to increased resistance to portal blood flow causing portal hypertension with a pressure gradient between portal and systemic circulation [9].

Portosystemic shunts result in reduced venous blood supply to the liver causing reduced perfusion and hence hepatic insufficiency [6, 9]. Histologically the liver of PSS patients have dilated lymphatics, arterial hyperplasia, and reduced numbers of veins [4]. The veins may be absent, collapsed, or small due to the reduced venous perfusion [4]. Reduced perfusion of the liver results in increased levels of toxins, ammonia, and bile acids in systemic circulation [4]. Increased levels of these substances especially ammonia leads to development gastrointestinal, urinary, and neurologic clinical signs [4, 6].

There are several other hepatic diseases that present with similar clinical signs and have similar histologic features as CEPSS [4, 6, 9]. Differential diagnoses for CEPSS include microvascular dysplasia, arteriovenous fistulae, hepatic neoplasia, hyperadrenocorticism, protein losing enteropathy, and gastrointestinal parasitism [4,6,9]. Portal vein hypoplasia (PVH) is histologically similar to CEPSS with similar clinical signs but lacks a macroscopic shunt; PVH

patients may also have ascites due to portal hypertension [4, 9]. Arteriovenous fistulae can also cause similar clinical signs as CEPSS but are characterized by macroscopic communications between the hepatic artery and portal vein [4]. This communication often results in portal hypertension and consequently ascites [4, 9]. Additionally, hepatic neoplasia can invade hepatic vasculature, compromising blood perfusion which may also lead to clinical signs similar to that seen with PSS [4].

Laboratory diagnostics provide information that guides veterinarians when considering treatment options for PSS patients [9]. Commonly used laboratory diagnostics include a complete blood count (CBC), serum biochemistry panel, pre- and postprandial bile acids test, and a urinalysis [1, 3, 9]. A postprandial bile acid test is 100% sensitive for detecting PSS [3]. Increased pre and postprandial bile acids in suspect cases of PSS is likely caused by the continued recirculation of bile acids via the shunt [6]. Ammonia tolerance tests are not appropriate for suspect PSS patients due to hyperammonemia and reduced capacity to produce urea. However, increased plasma ammonia concentrations are predictive of hepatic encephalopathy [6, 18]. Common abnormalities observed with a CBC include microcytosis with or without anemia and leukocytosis, and APSS patients may have a lower hematocrit [1]. However, it is not uncommon for a CBC to be unremarkable in PSS patients [9]. Common serum chemistry abnormalities include low albumin, low BUN, hypocholesterolemia, hypoglycemia, and moderately increased alkaline phosphatase (ALP) and alanine aminotrasfrase (ALT) [1 6]. Urinalysis of PSS patients often reveals low specific gravity due to polydipsia, hyperammonuria, and proteinuria [6].

In addition to laboratory diagnostics, there are several invasive and noninvasive diagnostic tools that are available for the diagnosis of PSS in dogs, some of which are available

in most general veterinary practices. Commonly used diagnostic tools available in most general practices include abdominal radiography and ultrasound [7]. Abdominal radiographs usually require no sedation and are a useful noninvasive method to evaluate hepatic size and confirm the presence or absence of abdominal effusion [1, 6, 9]. PSS patients often have microhepatica and bilateral kidney enlargement that can be observed with radiography [1, 7, 9]. Though radiography is convenient, it may be difficult to observe a PSS and radiolucent ammonium biurate stones [1, 6]. Abdominal ultrasound is the most commonly used tool in the diagnosis extrahepatic and intrahepatic PSS [1,7,13]. Ultrasonography does not commonly require sedation or general anesthesia and is highly sensitive and specific in diagnosis of PSS, ranging from 74-95% and 67-100% respectively, making it the diagnostic tool of choice [6, 9]. However, ability to diagnose PSS with ultrasound is dependent on operator experience [6, 9]. Ultrasound also allows for the visualization of radiolucent ammonium biurate stones and enlarged kidneys [6, 17]. Ultrasound Doppler and color flow can be used to identify and changes in blood flow and to determine blood flow velocity within a shunt [6, 17].

In addition to radiography and ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), scintigraphy, and portovenography may also be used [6, 9]. However, these tools may not be available in general practice or affordable for a patient owner. CT is a fast, noninvasive diagnostic tool that provides excellent visualization of shunting vessels, allowing for evaluation of morphology a more pre-surgical planning [6,9,12]. Similarly, MRI provides three-dimensional images that can also be used for surgical planning [19]. However, MRI is less sensitive than CT for the diagnosis of PSS and can be expensive [19]. Patients require sedation or general anesthesia for an adequate CT or MRI evaluation; however, PSS patients are often intolerant of general anesthesia [1, 6, 9]. Scintigraphy is a fast and noninvasive diagnostic tool

using the radioactive isotope pertechnetate technetium 99m (^{99m}Tc) [6, 9]. Technetium is administered as a bolus into the colon and is normally absorbed through colonic veins followed by the caudal mesenteric vein, portal vein, liver, and lastly the heart [6]. In a PSS patient, the isotope reaches the heart before the liver and then returns to the liver through the arterial circulation [6]. A less commonly used diagnostic tool due to its invasiveness is portovenography where contrast is injected directly into the mesenteric artery [6]. If diagnostic imaging reveals that there is no communication between the liver and portal system, the dog should not receive surgical attenuation or ligation of the shunt [9]. Diagnosis of PSS using diagnostic imaging allows for development of a treatment plan and pre-surgical planning. As part of pre-surgical preparation patients need to be stabilized with medical management.

The two primary treatment options for PSS are medical management and surgical treatment [9, 11]. The purpose of medical management is to stabilize PSS patients prior to surgery by reducing clinical signs, especially those observed with hepatic encephalopathy [9, 10, 11, 13, 20]. Medical management does not treat the physical anomaly; the purpose of surgical intervention is to treat the underlying physical shunt that is causing manifestation of clinical signs [20].

Medical management includes dietary changes, antibiotic therapy, lactulose, and anticonvulsant therapy such as levetiracetam (keppra) [9, 10, 13]. Common dietary changes include eating a highly digestible protein restricted diet to limit ammonia absorption [6, 9]. Oral neomycin is commonly used as a locally acting antibiotic to reduce numbers of bacteria that may produce toxins contributing to encephalopathy [2, 9, 15]. Lactulose is a semisynthetic disaccharide (laxative) that is used to treat hepatic encephalopathy; it works by acidifying the colon lumen, reducing ammonia absorption at the rectal mucosa [2, 9, 15]. Keppra is a commonly used anticonvulsant for the treatment of seizures; this medication does not undergo hepatic metabolism and so is useful

for PSS patients [15]. Keppra has been shown to significantly decrease the risk of postoperative seizures [10]. This multimodal approach helps to stabilize PSS patients prior to surgery [6, 9].

Once the patient is has been stabilized with medical management, surgery should proceed [13]. Common surgical treatment options include use of ameroid constrictor rings or cellophane bands to gradually attenuate the shunt reducing the risk of portal hypertension [9]. An ameroid ring (3.5 or 5 mm) placed around a shunt attenuates the vessel as the hygroscopic material inside the ring slowly swells and fibrosis develops around the vessel [9]. If the ring is too large for the patient, its weight can cause the vessel to kink, prematurely obstructing blood flow [9]. Cellophane bands rely on the body's inflammatory system to attenuate the shunt [9]. A cellophane band placed around a shunt attenuates the vessel by causing an acute inflammatory response followed by a chronic low-grade foreign body tissue response [9].

Surgical treatment is more beneficial than medical management for treatment of CEPSS and is the treatment of choice [9, 11, 13]. Surgical treatment results in significantly lower long term mortality rates (22%) and lower incidence of clinical signs (11%) than that observed with medical management (89% mortality rate, 83% incidence of clinical signs) [9, 11]. Though clinical signs and mortality rate are significantly lower with surgical treatment, possible complications of these surgical procedures include incisional hernia, ascites due to portal hypertension, abdominal pain, persistent shunting, hepatic encephalopathy, and development of multiple acquired shunts due to portal hypertension, and death [9, 11]. Due to the potential of these complications, these patients will require intense post-operative monitoring and follow up care [6, 9].

Post-operative monitoring and follow up care will need to continue to evaluate the patient for any complications and to decrease recovery time [9]. Immediately following surgery, PSS patients will require intravenous fluids to maintain hydration and organ perfusion, pain control, a

protein restricted diet, antibiotics, anticonvulsants, lactulose, and possible dextrose infusions [2, 6, 9]. Shunt attenuation is a gradual process and usually takes four to six weeks with cellophane band placement and two weeks or longer with ameroid ring placement [16, 19]. During this time and following the patient needs to be evaluated at follow-up exams [16]. Patient monitoring includes bile acid testing, urinalysis, abdominal radiographs or ultrasound, CBC, serum chemistry, and culture and sensitivity of urine, if urinary sings do not resolve [6, 16]. Fasting and postprandial bile acid levels should be re-evaluated at eight weeks since estimated closure time following surgery usually takes up to six weeks [16]. Prognosis is fair to good and mortality rates are low for CEPSS patients receiving surgical treatment [6, 9, 11]. Short term and long term survival rates following surgery are high with low prevalence of clinical signs [6, 11]. CEPSS patients can be treated surgically with a good chance of surviving without persistence of clinical signs.

In conclusion, CEPSS is a life threating condition common in young dogs that is characterized by vascular anomalies in which venous portal blood bypasses the liver [4, 6, 9]. In these dogs, functional capacity of the liver is impaired leading to the accumulation of various substances in systemic circulation including toxin, bile acids, ammonia, and nutrients [4, 8]. Presentation of gastrointestinal, urinary, and neurologic clinical signs is due to the buildup of these substances in systemic circulation [4, 6, 9]. Various diagnostic tools aid in the diagnosis of CEPSS and allow for pre-surgical planning [6]. Patients receiving surgical treatment have lower incidence of clinical signs and higher survival rates than those receiving medical management, making surgical intervention the treatment of choice [6, 9, 11]. CEPSS are treatable and can often be resolved with proper intervention and follow up care [6].

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