BENEFICIAL NUTRITION
Diet can play an instrumental role for patients with portosystemic shunts, potentially providing a beneficial effect on their quality of life.

NUTRITION NOTES

Dietary Requirements for Patients with Portosystemic Shunts

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Portosystemic shunts (PSS), which are vascular liver disorders, lead to derangements in blood flow through the liver, which allow blood from the gastrointestinal tract direct access to the systemic circulation, bypassing the liver. PSS can result in hepatic insufficiency, allowing toxic substances, such as ammonia, to build up in the systemic circulation, leading to hepatic encephalopathy (HE) if not properly managed.

PSS can be categorized as congenital or acquired. Congenital PSS is the most common congenital vascular disorder, and acquired vascular disorders (also known as multiple acquired PSS) are usually a consequence of chronic liver disease and portal hypertension.

Congenital PSS can be further subdivided into extrahepatic or intrahepatic shunts. Extrahepatic shunts are more usually from the portal vein or a tributary outside the liver and more commonly affect small and toy breeds (e.g., Yorkshire terriers, Cairn terriers, Maltese, miniature schnauzers), whereas intrahepatic shunts arise from an intrahepatic portal vein branch within the liver parenchyma and more commonly affect large-breed dogs (e.g., Doberman pinschers, Old English sheepdogs, Irish wolfhounds). Congenital PSS leads to many clinical signs, most commonly in the neurologic, gastrointestinal, and urinary systems (TABLE 1).

Clinical signs of PSS can decrease quality of life and survival times, and the recommended treatment and management options include various methods of surgical attenuation (e.g., acute suture ligation, ameroid constrictors, cellophane banding, endovascular coils) and medical management (e.g., dietary management, synthetic disaccharide administration, antimicrobial administration).[4-6] For most patients, surgical attenuation is recommended and is associated with a significantly better survival rate than medical management.[4] However, for some patients, the location of the shunt and the cost of surgery make medical management the only viable long-term option. Medical management is crucial for all patients, including those undergoing future surgical treatment, to help minimize the potential for postoperative seizures[1] and for postoperative monitoring and management as complete attenuation is gradually and not always completely achieved.[7] Medical management can be implemented and monitored by primary veterinarians and clients together and can lead to a good quality of life if proper steps are taken to minimize the potential build-up of ammonia and other toxic substances that lead to the negative signs of PSS, mainly HE, although another

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TABLE 1 Common Clinical Signs of Dogs and Cats With Portosystemic Shunts[1-3]

SYSTEM	SIGNS
Neurologic (hepatic encephalopathy)	▪ Behavior alterations ▪ Reduced levels of consciousness ▪ Ataxia ▪ Circling ▪ Head pressing ▪ Blindness ▪ Seizures ▪ Stupor, coma
Gastrointestinal	▪ Vomiting ▪ Diarrhea ▪ Gastrointestinal bleeding ▪ Pica ▪ Small size (often the runt of the litter) ▪ Poor body condition
Urinary tract (resulting from urate urolithiasis)	▪ Hematuria ▪ Dysuria ▪ Stranguria
Other signs	▪ Sedative/anesthesia intolerant ▪ Copper-colored iris (cats) ▪ Ptyalism (cats)

TABLE 2 Functions of the Liver That Necessitate Appropriate Nutrition

FUNCTION	SPECIFIC ACTIONS
Carbohydrate metabolism	▪ Glucose metabolism (glycolysis, gluconeogenesis, glycogenolysis) ▪ Glycogen storage
Lipid metabolism	▪ Triglyceride metabolism and storage ▪ Cholesterol synthesis, esterification, excretion ▪ Lipoprotein synthesis (apoproteins) ▪ Phospholipid metabolism
Protein metabolism	▪ Protein synthesis (albumin) ▪ Fibrinogen production ▪ Coagulation proteins (proteins C, S, II, VII, IX, X) production ▪ Anticlotting proteins (plasminogen, antithrombin) production ▪ Acute-phase proteins production
Vitamin and mineral metabolism and storage	▪ Bile acid facilitation of fat-soluble vitamin absorption ▪ Vitamin and mineral storage (A, D, E, small amounts of K and B_{12}, copper, iron) ▪ Ceruloplasmin, transferrin, retinal-binding protein, thyroxine-binding globulins
Immune function	▪ Kupffer cell clearance of intestinal pathogens, particulates, and damaged cells ▪ IgA in bile ▪ Complement and interleukin metabolism
Detoxification and excretion	▪ Excretion of nitrogenous waste via conversion of ammonia to urea (urea cycle) ▪ Bile secretion ▪ Biotransformation and detoxification of drugs and toxins

consequence of PSS can be ammonium urate urolithiasis.

BRIEF PATHOGENESIS OF HEPATIC ENCEPHALOPATHY

The liver is an essential organ that is involved in many metabolic functions, including metabolism of protein, fat, and carbohydrate; metabolism and storage of vitamins and minerals; and detoxification and excretion of nitrogenous waste. The liver is the main site of ammonia detoxification, which occurs either in periportal hepatocytes in the urea cycle or in perivenous hepatocytes, synthesizing glutamine from glutamate and ammonia.[2] Ammonia is produced in 2 ways: urease-producing gastrointestinal microbial organisms produce ammonia by breaking down nitrogenous products (e.g., urea), and gastrointestinal enterocytes metabolize glutamine to produce ammonia.[2] Patients with PSS may experience inadequate ammonia detoxification, and successive increased circulating ammonia concentration (hyperammonemia) can lead

TABLE 3 Factors That Are Multiplied by RER to Determine Maintenance (or Daily) Energy Requirements

FACTOR	DOG	CAT
Young animal <4 mo	3	3
Young animal ≥4 mo	2	2
Intact adult, active	1.8	1.4
Spayed/neutered adult, active	1.6	1.2
Prone to being overweight or obese	1–1.2	1
Hospitalized patients/critical care	1	1
Spayed/neutered adult, lower activity level	1.2–1.4	1–1.1

RER=resting energy requirement

TABLE 4 Sample Calculated Calorie Requirements for 2 Typical PSS Patients

REQUIREMENT	YORKSHIRE TERRIER, 8-MONTH-OLD, INTACT FEMALE, 2 KG	IRISH WOLFHOUND, 5-YEAR-OLD, NEUTERED MALE, ACTIVE, 50 KG
RER (RER = 70 × $BW_{kg}^{0.75}$)	▪ 118 kcal/day	▪ 1316 kcal/day
MER factor	▪ 2	▪ 1.6
MER	▪ 236 kcal/day	▪ 2106 kcal/day
Recommended daily diet amount (90% of MER)	▪ 212 kcal/day	▪ 1896 kcal/day
Maximum treat allowance to prevent unbalancing diet (10% of MER)	▪ 24 kcal/day	▪ 210 kcal/day
Examples of appropriate treats that fit within the daily treat allowance	▪ 5 g air-popped popcorn, no salt or butter (~19 kcal) ▪ 1 tbsp applesauce (~6 kcal)	▪ 40 g raw blueberries (~24 kcal) ▪ 40 g raw apples (~20 kcal) ▪ 40 g cooked chickpeas (garbanzo beans), no salt (~66 kcal) ▪ 50 g raw carrots (~20 kcal) ▪ 50 g cooked black beans, no salt (~66 kcal) ▪ ½ tsp honey (~11 kcal)

BW=body weight; MER=maintenance energy requirement; PSS=portosystemic shunts; RER=resting energy requirement

to neurologic signs and severe skeletal muscle atrophy. For these patients, appropriate nutrition is crucial.

The goals of therapy for patients with HE include recognizing and correcting the precipitating causes (e.g., gastrointestinal bleeding, constipation, hypokalemia), reducing intestinal production and absorption of toxic substances, and providing symptomatic and supportive care.[8,9]

ROLE OF DIET AND NUTRITION

The ideal diet for management of PSS should be complete and balanced, highly palatable, and highly digestible; should contain appropriate protein, both in quantity and type; and should supply appropriate quantities of vitamins and minerals, to provide essential nutrients to perform the many functions of the liver (**TABLE 2**).

Energy and Protein

Meeting energy and protein needs is critical as protein and energy malnutrition can lead to substantial problems (e.g., muscle loss). Patients with liver disease, such as those with PSS, may experience inadequate ammonia detoxification and a gradual increase of hyperammonemia, which can lead to severe skeletal muscle atrophy, increased apoptosis, and reduced protein synthesis, all of which are further detriments to muscle size and strength.[10] Thus, appropriate amounts of energy and protein must be provided.

Energy requirements for individual patients should ideally be based on a complete diet history; however, for ease, calculations are often used. Many formulas exist to determine energy needs, but the author's preference for calculating resting energy requirement (RER) for dogs is to use the patient's body weight (BW) in kg to the power of 0.75 (RER dogs = 70 × $BW_{kg}^{0.75}$) and for cats the same formula to the power

TABLE 5 Veterinary Therapeutic Diets and Nutrients to Consider for Nutritional Management of PSS in Dogs[a]

NAME	PROTEIN SOURCE	PROTEIN G/1000 KCAL (% ME)	FAT G/1000 KCAL (% ME)	CARBOHYDRATE G/1000 KCAL (% ME)	TOTAL DIETARY FIBER G/1000 KCAL	SODIUM G/1000 KCAL
Royal Canin Vegetarian dry	Oat and potato protein	53.5 (20)	28.1 (25)	151.1 (55)	32.1	0.8
Royal Canin Vegetarian canned	Soy protein isolate	79.3 (31)	33.6 (31)	98.7 (38)	16.3	1.5
Royal Canin Hepatic dry	Soy protein isolate	40.6 (15)	40.6 (36)	133.6 (49)	18.3	0.5
Royal Canin Hepatic canned	Pork byproduct, chicken liver	45.8 (17)	28.2 (25)	157.9 (58)	12	0.6
Royal Canin UC Low Purine dry	Egg product	50.6 (19)	37.9 (34)	127.9 (47)	14.4	0.8
Royal Canin Urinary SO + Hydrolyzed Protein dry	Hydrolyzed soy	52.9 (20)	39.7 (35)	122.2 (45)	18.2	3.4
Royal Canin Ultamino dry	Hydrolyzed poultry feather	45.9 (17)	42 (37)	125.4 (46)	14.8	1.8
Hill's Prescription Diet l/d dry–liver diet	Chicken, egg product	42 (15)	53 (45)	115 (40)	15	0.42
Hill's Prescription Diet l/d canned–liver diet	Soybean meal, egg product	44 (15)	54 (46)	111 (39)	17	0.5
Hill's Prescription Diet u/d dry	Egg product	32 (11)	48 (41)	138 (48)	9	0.51
Hill's Prescription Diet u/d canned	Egg product, pork liver	30 (10)	57 (49)	116 (41)	8	0.62
Hill's Prescription Diet Derm Complete dry	Egg product	43 (15)	44 (36)	148 (50)	11	0.54
Hill's Prescription Diet Derm Complete canned	Egg product	49 (17)	41 (35)	138 (48)	12	0.88
Purina Pro Plan Veterinary Diet HA Hydrolyzed Vegetarian Formula dry	Hydrolyzed soy protein isolate	53.6 (20)	26.5 (24)	149.3 (56)	11.6	0.9

[a]*Values are provided by Royal Canin, Hill's Prescription Diet, and Purina product guides. Values are subject to change; therefore, clinicians should verify current nutrient content with up-to-date information from the provider.*
ME=metabolizable energy; PSS=portosystemic shunts

of 0.67 (RER cats = 70 × $BW_{kg}^{0.67}$). Daily energy requirements or maintenance energy requirements (MER) are usually calculated by using a factor multiplied by RER (**TABLE 3**). The factor used depends on the animal's age, spay/neuter status, and activity level. Hospitalized animals are typically fed to meet their RER (MER factor of 1); however, for young animals, the factor used should be appropriate to their age. For dogs that are not hospitalized, the factor used should better meet their energy needs, depending on their age, spay/neuter status, and activity level. Sample calculations for 2 typical PSS patients are shown in **TABLE 4**.

Protein is of the utmost importance in the dietary management of patients with PSS. The appropriate amount of protein is not so excessive that it causes HE but not so restricted that it impedes the many functions of the liver. Patients with PSS may have increased protein requirements, and dietary protein should not be restricted in patients that are not encephalopathic.[8] In addition, providing the right type of protein can significantly affect a patient with PSS. Vegetable and dairy protein sources are often recommended to help mitigate the possibility of HE.[8,11] The most common causes of HE in animals with severe liver disease or PSS are ingestion of a meat-based high-protein diet, gastrointestinal bleeding, and azotemia.[8] For dogs with experimentally created PSS that were fed a dairy-based diet compared with a meat- or fish-based diet, survival times were significantly prolonged, weight loss was less, and signs of encephalopathy were fewer and less severe.[12]

TABLE 6 Veterinary Therapeutic Diets and Nutrients to Consider for Nutritional Management of PSS in Cats[a]

NAME	PROTEIN SOURCE	PROTEIN G/1000 KCAL (% ME)	FAT G/1000 KCAL (% ME)	CARBOHYDRATE G/1000 KCAL (% ME)	TOTAL DIETARY FIBER G/1000 KCAL	SODIUM G/1000 KCAL
Royal Canin Feline Urinary SO + Hydrolyzed Protein dry	Hydrolyzed soy protein	71.3 (36)	42.2 (29)	99.8 (35)	26.1	3.4
Royal Canin Feline Ultamino dry	Hydrolyzed poultry feather	62.6 (23)	43.4 (38)	106.5 (39)	20.4	2.8
Royal Canin Feline Hydrolyzed Protein HP dry	Hydrolyzed soy protein	62.5 (23)	49 (43)	94.4 (34)	20.1	1.5
Purina Pro Plan Veterinary Diets NF Kidney Function Advanced Care Feline dry	Tuna and soy protein	69.2 (26)	41.4 (38)	95.4 (36)	25.7	0.7

[a]Values provided by Royal Canin and Purina product guides. Diets are subject to change; therefore, clinicians should verify current nutrient content with up-to-date information from the provider.
ME=metabolizable energy; PSS=portosystemic shunts

It is thought that heme and other nitrogenous bases in meat diets contribute to exacerbation of HE, leading to shorter survival times.[8,12] Dogs experiencing urate stones or HE should be fed protein below its "threshold," which includes treats. Clients should be counseled to provide vegetable-based treats rather than meat-based treats whenever possible. Protein contents of veterinary therapeutic diets can be compared to determine appropriately controlled protein diets for dogs and cats (**TABLES 5 AND 6**).

Bacterial metabolism of dietary protein from meats is rich in aromatic amino acids (tryptophan, tyrosine, phenylalanine), whereas vegetable proteins are richer sources of branched-chain amino acids (leucine, isoleucine, valine) and produce less ammonia when fermented.[1] Many veterinary therapeutic diets capitalize on the potentially favorable amino acid profiles of vegetables.

Traditionally, veterinary therapeutic renal diets have been considered as potential options for management of patients with PSS due to the protein restriction; however, the source of protein and the degree of protein restriction in renal diets may not be the best management approach for all patients with PSS. However, for some dogs that have severe HE and require severe protein restriction, renal diets may help mitigate encephalopathy.

More appropriate are veterinary therapeutic diets that have been formulated for management of many liver diseases, including PSS but also copper storage disease. For some dogs, however, even these diets may be too protein restrictive and alternative options can be considered. For patients that do not improve with an appropriate therapeutic diet, have multiple diseases, or have issues of palatability, consulting a board-certified veterinary nutritionist is recommended. Diets that contain egg or vegetable-based proteins are available as veterinary therapeutic diets and may provide more protein as well as additional fiber that can help manage PSS.

Dogs with underlying liver disorders are predisposed to urate urolithiasis due to the hyperammonuria and hyperuricosuria that result from the liver's reduced ability to convert ammonia to urea and uric acid to allantoin.[13] Management of urate stone–producing patients should always include increasing water intake, ideally to achieve a urine specific gravity of <1.02 for dogs or <1.025 for cats, and providing a low-purine diet, although vegetarian diets have also been used to manage these patients.

Fiber

Dietary fiber can reduce the availability and production of nitrogenous waste in the gastrointestinal tract. Fiber, whether from a higher-fiber content in the diet or supplemented in addition to the diet, can also affect the microbiome by acting as a prebiotic.

- Consider fiber supplementation if a low-fiber diet is being fed. Gradually add fiber to the diet and evaluate the patient's response. Each animal will respond differently to fiber supplementation, including to the type of fiber provided. Some dogs may experience improved stool quality while others may experience constipation or diarrhea; therefore, close monitoring of response to supplementation is recommended.

- Always provide plenty of fresh water when supplementing fiber.
- The author's personal preferences are to use the following fiber supplementation options:
  - Psyllium husk fiber (mixed source of fiber) can be added to the food (¼ to 1 teaspoon q24h or q12h, depending on the size of the dog and its tolerance).
  - Powdered cellulose (insoluble fiber) can be added to the food (1 to 3 g q24h or q12h), depending on the size of the dog and its tolerance.

Sodium

Ascites can be a negative consequence of liver disease and PSS; for these patients, consider diets with a lower sodium content to help mitigate ascites.

Feeding Schedule

To help reduce the amount of dietary protein that reaches the colon, smaller meals fed more frequently are often recommended.

Nonabsorbable Disaccharides

Lactulose, a nonabsorbable disaccharide, is fermented by the gastrointestinal microbiota to produce volatile fatty acids, decrease colonic pH, and decrease transit time.[2] Beneficial effects can include:

- Trapping of ammonium ions within the colon, thus decreasing absorption into portal circulation
- Inhibiting ammonia production in colonic bacteria
- Reducing intestinal transit times when used as an osmotic laxative, which further decreases bacterial ammonia release and leads to faster excretion of fecal nitrogenous compounds.

Dosages are as follows:

- **Dogs:** 0.5 to 1 mL/kg q8h to q12h PO (goal: 2 to 3 soft stools daily)
- **Cats:** 0.5 to 5 mL/cat q8h to q12h PO (goal: 2 to 3 soft stools daily)

A recent retrospective study noted that when nonsurgical congenital PSS patients were fed diets with or without lactulose, overall estimated median survival times did not differ significantly between groups.[3] Thus, some patients may be managed by dietary intervention alone; some more severely affected patients may require more intensive management, including lactulose; and the most severely affected patients may require antimicrobial therapy to further modulate the microbiome.

Treats

For most clients, treats are a valuable part of their daily pet interactions; thus, appropriate options are needed to prevent potential negative consequences (e.g., HE, urate stone formation). High-protein foods should be avoided (e.g., pieces of meat, some biscuits, rawhide treats, jerky treats, freeze-dried treats, pig's ears, pizzle sticks). Good options are fruits and vegetables. Popcorn and applesauce are excellent options, particularly for low-calorie treat allowances, such as for toy breeds, but commercial treats can also be considered. To avoid unbalancing the diet, the caloric content of treats should be limited to 10% of total caloric intake (**TABLE 4**). Calories from whole foods can be determined by using the United States Department of Agriculture Nutrient Database at fdc.nal.usda.gov. Counsel owners not to feed foods that are harmful, such as foods with xylitol, garlic, onions, macadamia nuts, grapes, and raisins.

TIPS FOR SELECTING AN APPROPRIATE DIET

The following tips, along with **TABLES 5 AND 6**, can help with selection of an appropriate therapeutic diet for nutritional management of PSS patients, whether pre- or postsurgically or for medical management.

Consider protein source and amount.

- If HE is present, choose lower-protein and vegetable-source protein diets.
  - Consider higher-fiber diets, if tolerated/palatable.
  - To manage HE, consider adding lactulose as well as antibiotics (depending on the severity of the case).
- If HE is not present, consider gradually increasing dietary protein and monitoring clinical signs and liver function parameters (e.g., blood urea nitrogen, total protein, albumin, cholesterol, clotting times, bile acids).
- For cats, because of their unique metabolic requirements, consider renal diets if protein restriction less than that provided by the suggested diets in **TABLE 6** is needed.
- Other considerations:
  - If ascites is present, choose lower-sodium options.
  - If urate stones are present, consider urinary diet options and increase water intake.
  - Postsurgical patients will benefit from the diets shown in **TABLES 5 AND 6** until complete attenuation has been achieved. Success should be monitored and confirmed with imaging and

blood work, and careful monitoring should continue as multiple acquired PSS can occur postsurgically, leading to a need for lifetime medical management regardless of the surgical correction.

- Patients with other nutritionally managed diseases may benefit from other options.
  - Consider hydrolyzed diets for chronic enteropathy and food allergy patients.
  - Consider lower fat content for dogs with pancreatitis or hypertriglyceridemia.

Although many available veterinary therapeutic diets are appropriate for most PSS patients, some situations preclude use of the diets listed in **TABLES 5 AND 6**. Whether because of patient refusal, client preference, or complex comorbidities of the patient, home-prepared diets are occasionally needed to ensure provision of adequate protein and energy as well as all essential nutrients. If necessary, a board-certified veterinary nutritionist should review the case to help formulate an appropriate home-cooked diet. Monitoring should include ensuring that the recipe is followed and that all supplements and ingredients are consumed according to recommendations. Special considerations may be necessary for young growing animals, particularly large-breed dogs, which may pose interesting challenges.[14] A list of specialists able to provide guidance can be found at acvn.org.

SUMMARY

Whether it is used for short-term management before or immediately after surgical correction or long-term medical management, diet can play an instrumental role and can provide a beneficial effect on the quality of life of PSS patients. The most substantial consequences of PSS are neurologic, although urinary and gastrointestinal signs are also noted if appropriate nutritional management is not carefully followed. The touchstone of nutritional PSS management is feeding a complete and balanced diet with adequate calories and appropriate protein (amount and type). Unnecessary protein restriction for patients without HE can lead to further muscle loss and can further impair the already taxed liver. Typically recommended are vegetable- and/or dairy-based complete and balanced diets as these proteins are better tolerated and can often provide protein in higher quantities due to a favorable nutrient profile. Patients with complex comorbidities may require control or reduction of other nutrients (e.g., lower sodium for patients with ascites or heart disease, hydrolyzed diets for patients with food allergies or chronic enteropathies). Special cases may require guidance from a board-certified veterinary nutritionist.

TAKE-HOME POINTS FOR NUTRITIONAL MANAGEMENT OF PATIENTS WITH PSS

Nutritional management of PSS:

- For diet and treats, provide vegetable or dairy sources of protein instead of meats, being especially careful to avoid organ meats.
- Feed smaller meals, feed more often, and ensure adequate energy intake to prevent lean muscle loss.

Additional nutritional modifications depending on clinical signs of each patient:

- If the PSS patient is exhibiting signs of protein intolerance (e.g., HE, urate stones):
  - Reduce protein intake, ideally to just below the threshold that causes HE.
  - Consider the fiber content of the diet; if feeding a lower fiber diet, consider supplementing intake with additional fiber.
  - Lactulose may be required to help mitigate signs of HE; dose should be adjusted to each patient's response. The goal should be 2 to 3 soft stools daily.
  - If the above steps are ineffective at mitigating signs of HE, consider using antibiotics to further modify bacteria.
- If the PSS patient is not experiencing HE:
  - Provide as much protein as is tolerated without creating negative signs (i.e., HE, urate stones).
  - Remember that fiber supplementation and lactulose may be required to help mitigate negative clinical signs. **TVP**

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