Association of portovenographic findings with outcome in dogs receiving surgical treatment for single congenital portosystemic shunts: 45 cases (2000–2004)

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Objective—To determine whether hepatic portal vasculature, as assessed by intraoperative mesenteric portovenography (IMP), is related to outcome in dogs undergoing attenuation of single congenital portosystemic shunts (CPSSs).

Design—Retrospective case series.

Animals—45 dogs, each with a single CPSS, in which IMP was performed before and after temporary complete occlusion of the shunting vessel and that underwent complete (17 dogs) or partial (28 dogs) CPSS attenuation (surgery 1).

Procedures—Medical records were reviewed for signalment, clinical history, and bile acids stimulation test results. Intrahepatic portal vessel (IPV) opacification in pre- and postocclusion portovenograms was graded to determine whether the degree of opacification was correlated with the degree of shunt attenuation, clinical or biochemical factors, or long-term clinical outcome. In 17 of 28 dogs that had partial CPSS attenuation, these procedures were subsequently repeated (surgery 2) to achieve complete (14 dogs) or further partial (3 dogs) CPSS attenuation.

Results—Compared with preattenuation findings, IPV opacification increased significantly after partial or complete CPSS attenuation. The degree of IPV opacification before and after CPSS occlusion (surgery 1) was greater in dogs that tolerated complete versus partial CPSS attenuation and was correlated positively with age. The degree of IPV opacification following CPSS occlusion (surgery 1) was maximal in all dogs without encephalopathy and was correlated negatively with follow-up preprandial serum bile acids concentrations and positively with clinical improvement.

Conclusions and Clinical Relevance—Data suggest that IMP can be used to assess changes in IPV blood flow and help predict outcome following attenuation of single CPSSs in dogs. (J Am Vet Med Assoc 2006; 229:1122–1129)

In dogs with CPSSs, most of the portal blood bypasses the liver and enters the systemic circulation. As a result, the liver lacks a normal portal supply of metabolites and growth factors, for which an increase in arterial blood supply cannot fully compensate. Histologic lesions in dogs with CPSSs include hypoplasia of intrahepatic portal veins, proliferation of hepatic arterioles, congestion of central veins and sinusoids, bile duct proliferation, hepatocellular atrophy, Kupffer cell hyperplasia, cytoplasmic vacuolization, and diffuse fatty infiltration. Surgical attenuation of a CPSS is intended to redirect portal blood flow through the liver to promote normalization of hepatic structure and function. However, hypoplasia of the intrahepatic portal veins may restrict portal blood flow into the liver leading to portal hypertension and the development of multiple acquired portosystemic shunts or death.

Intraoperative mesenteric portovenography has been used in dogs and cats for diagnosis and morphologic assessment of portosystemic shunts. Injection of contrast medium into a mesenteric vein typically results in opacification of the portal vein and the intrahepatic portal vasculature so that the number, distribution, and caliber of vessels may be assessed.

Intraoperative mesenteric portovenography has been used to assess the portal vasculature in dogs and cats with CPSSs. MacDonald et al designed 2 scoring systems for use with IMP. The first system involved a visual analogue scale in which 1 end of a 100-mm line represented no evidence of a portal vein entering the liver and the other end represented normal hepatic vasculature. This system was both reliable and repeatable between 2 observers, but was dependent on the experience of observers. Nonetheless, this scoring system was used to determine that intrahepatic portal blood flow increased immediately following CPSS attenuation and that intrahepatic portal blood flow was significantly higher in dogs and cats that underwent complete versus partial shunt attenuation. However, the authors of that study concluded that there was no clear quantifiable relationship between the degree of shunt attenuation that was achieved and the IMP score. The second system was a numeric scoring scale that was based on 13 closed questions (yes or no answers). The questions sought to clarify the presence or absence of a portal vein entering the liver; principal right and left portal branches; branching of the principal portal branches; primary, secondary and tertiary branching of the principal portal branches; and opacification of the right and left lobes of the liver. This scheme also

**Abbreviations**

| CPSS | Congenital portosystemic shunt |
| IMP | Intraoperative mesenteric portovenography |

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appeared to be reliable and repeatable between observers, and required less experience; however, the questions used did not represent an equal linear progression from the previous question, and therefore, comparisons with continuous variables would be difficult. In addition, the numeric scoring scale was not equally applicable to extrahepatic and intrahepatic portosystemic shunts and incorrectly assumed equality of the principal right and left portal branches.

The purpose of the study reported here was to determine whether hepatic portal vascularity, as assessed by IMP, is related to outcome in dogs undergoing attenuation of single CPSSs. We hypothesized that the development of the intrahepatic portal vasculature, as assessed by IMP, could be used as a predictor of outcome following attenuation of CPSS in dogs. To investigate this hypothesis, data were collected regarding dogs that were each treated surgically for a single CPSS and for which IMP was performed before and after temporary complete occlusion of the shunting vessel during those surgical treatments. By grading portovenograms according to degree of opacification of the intrahepatic portal vasculature, it was our intent to quantify the development of the intrahepatic portal vasculature and to determine whether degree of opacification of the intrahepatic portal vasculature was correlated with the degree of shunt attenuation, clinical or biochemical factors, or long-term clinical outcome.

Criteria for Selection of Cases

Medical records of all dogs that underwent surgical attenuation of a single intra- or extrahepatic CPSS at the Royal Veterinary College from August 2000 to July 2004 were reviewed. Dogs in which IMP was performed before and after temporary complete occlusion of their CPSS were selected for inclusion in the study. Records were available for 48 dogs that had undergone attenuation of a single CPSS, and 45 dogs met the inclusion criterion.

Procedures

Preoperative details obtained from each medical record included age, breed, sex, body weight, clinical signs, duration of clinical signs prior to surgery, medical treatments administered prior to surgery, duration of and clinical response to those medical treatments, and bile acids stimulation test results. Clinical signs were divided into 5 categories according to the body systems that were involved as follows: neurologic, gastrointestinal, urinary, musculoskeletal with particular reference to growth, and other. For each dog, a grade was assigned on the basis of the presence or absence of each of the aforementioned categories of clinical signs and the total number of categories of clinical signs present. This numerical grading system of number of clinically affected body systems was used to determine objectively whether or not surgical CPSS attenuation resulted in resolution of clinical signs in a manner that could be verified by use of statistical methods and was not intended as a measure of severity of clinical signs. Clinical response to medical treatments was also subjectively graded as follows: poor (little if any clinical improvement), partial (some improvement, but clinical signs of a CPSS still present), or complete (no remaining clinical signs). Anesthesia records and surgical reports were reviewed for information regarding perioperative drug administration, CPSS type, whether partial or complete CPSS attenuation was performed, portal pressures before and after temporary complete CPSS occlusion, and surgical complications. Kennel logs and discharge notes were reviewed for short-term postoperative complications (defined as those that developed prior to suture removal at 10 to 14 days after surgery).

Records of follow-up examinations performed at least 1 month after the initial surgery (designated as surgery 1) for CPSS attenuation were reviewed. Following surgery 1, all dogs continued to receive their preoperative medical treatments for CPSS pending confirmation of an improvement in hepatic function. For dogs that had not received medical treatment prior to surgery 1, postoperative treatment consisted of a low-protein diet. For dogs that underwent partial CPSS attenuation, it was recommended that a second surgery (designated as surgery 2) to achieve further shunt attenuation should be performed 2 to 3 months following surgery 1. In addition, follow-up IMP was recommended for any dog requiring anesthesia for purposes of neutering. The same information recorded for the initial surgery was also recorded for follow-up examinations, except that clinical response to surgery 1 was recorded instead of clinical response to medical management. Clinical response to surgery 1 was graded subjectively as follows: poor (little if any clinical improvement), partial (some improvement, but clinical signs of a CPSS still present), and complete (no remaining clinical signs).

Surgery—Partial or complete CPSS attenuation was performed by use of 2-0 ligatures of silk or polypropylene suture according to previously published techniques. Briefly, a cranioventral midline celiotomy was performed. A mesenteric vein was catheterized for direct measurement of portal pressure with a comprehensive anesthetic patient monitor. The same mesenteric catheter was used for IMP, which was performed before and after temporary complete CPSS occlusion performed by use of a Rummel tourniquet. The decision to partially or completely attenuate a CPSS was made on the basis of portal pressure, visual assessment of the pancreas and intestines for signs of portal hypertension, central venous pressure, and arterial blood pressure according to previously published recommendations. Complete CPSS attenuation was performed when complete CPSS occlusion did not result in portal pressure > 18 mm Hg, persistent evidence of portal hypertension on visual inspection of the intestines and pancreas, a change in central venous pressure of > 1 mm Hg, or a change in direct arterial pressure of > 5 mm Hg. In dogs undergoing partial CPSS attenuation, a second ligature was tied loosely around the CPSS and left in situ to facilitate further CPSS attenuation at a later date.

Portovenography—Digital subtraction IMP was performed by use of a mobile C-arm device according to previously published techniques. A bolus (1 mL/kg [0.45 ml/lb]) of an iodine contrast agent was...
injected into a mesenteric vein for each portovenogram. The mesenteric vein was catheterized with a large-bore catheter (20 or 22 gauge), and the bolus of contrast agent was injected manually as quickly as possible. Images were acquired at a rate of 1 second from the start of the injection until opacification of the portal vasculature faded. Each series of images was examined subjectively, and the image with maximal opacification of the intrahepatic portal vasculature was selected for further analysis.

Analysis of portovenograms—Portovenograms obtained before temporary complete occlusion was performed during surgery 1, after occlusion was performed during surgery 1, before occlusion was performed during surgery 2, and after occlusion was performed during surgery 2 were assessed (4 groups). Prints of all portovenograms were placed together in random order, and each was assigned an arbitrary number; portovenograms were graded according to the number of branch generations of intrahepatic portal vessels (Figure 1) by 2 observers who reached a consensus without reference to any clinical data. Portovenograms in which the distribution of portal blood flow among liver lobes appeared markedly uneven were assessed in the same manner as portovenograms in which the distribution appeared more uniform. One observer was a board-certified radiologist (CRL), and the other was a surgery resident (KCLL). Postocclusion portovenograms for surgery 2 were not available for 2 dogs; because the preoclusion portovenograms obtained during surgery 2 were grade 4, it was assumed that the postocclusion portovenograms for these dogs would also have been assigned a grade of 4.

Statistical analysis—The significance of differences in portovenogram grades before and after temporary complete CPSS occlusion during surgeries 1 and 2 was assessed by use of the Wilcoxon signed rank test. The significance of the difference between the preoclusion portovenogram grade during surgery 1 and the preocclusion portovenogram grade during surgery 2 and the difference between the postocclusion portovenogram grade during surgery 1 and the postoclusion portovenogram grade during surgery 2 were assessed by use of the Wilcoxon signed ranks test (only data from dogs that underwent 2 surgeries were analyzed). Correlations between either pre- or postocclusion portovenogram grades for surgery 1 and age, weight, duration of clinical signs prior to surgery, duration of appropriate medical treatment prior to surgery, serum bile acids concentration, portal pressure, and number of body systems that were clinically affected were assessed by use of the Spearman rho correlation test. Associations between either pre- or postocclusion portovenogram grades for surgery 1 and body systems that were clinically affected, type of shunt (intrahepatic vs extrahepatic), partial or complete shunt attenuation, presence or absence of short-term complications, and short-term survival were assessed by use of the Mann-Whitney test. Correlations between either pre- or postocclusion portovenogram grades for surgery 1 and clinical response to medical treatment or clinical response to first surgery were assessed by use of the Kruskal-Wallis test. Where appropriate, the significance of differences between factors at surgery 1 and factors at follow-up examination or surgery 2 was assessed by use of the paired Student t test for continuous variables, the Wilcoxon signed rank test for discontinuous variables, and the Fisher exact test for bivariate variables. All statistical analyses were carried out by use of a standard statistics software package. A value of $P < 0.05$ was considered significant.

Results

Dogs—Forty-five dogs met the inclusion criteria for the study, including 34 dogs with a single extrahepatic CPSS and 11 dogs with a single intrahepatic CPSS. Intraoperative mesenteric portovenography was performed before and after temporary complete occlusion of the CPSS in all 45 dogs (surgery 1). During surgery 1, complete CPSS attenuation was performed in 17 (38%) dogs and partial CPSS attenuation was performed in 28 (62%) dogs. Two to 13 months later (median interval, 3 months), 19 dogs underwent a second surgery (surgery 2); of these dogs, 2 had complete CPSS attenuation and 17 had partial CPSS attenuation performed during surgery 1. In the 2 dogs that had complete CPSS attenuation performed during surgery 1, repeat IMP was performed at the owner’s request at the time that the dogs underwent ovariohysterectomy. In these 2 dogs, IMP findings confirmed persistent lack of flow through the CPSS. In the 17 dogs that had partial CPSS attenuation performed during surgery 1, IMP was performed before and after temporary complete CPSS occlusion during surgery 2 and was followed by complete CPSS attenuation in 14 dogs and partial CPSS attenuation in 3 dogs. As a result, 126 portovenograms were available for assessment.

Among the dogs that composed the study population, the median age was 12 months (range, 2 to 103 months) and the median weight was 7.5 kg (16.5 lb; range, 1.0 to 50.0 kg [2.2 to 110 lb]). There were 17 sexually intact males, 9 castrated males, 13 sexually intact females, and 6 spayed females. Twenty-three pure breeds were represented including 6 Yorkshire terriers, 6 West Highland White Terriers, 4 Shih Tzus, 3 Cairn Terriers, 3 Jack Russell Terriers, 2
Norfolk Terriers, 2 Bichon Frises, 2 Miniature Poodles, 2 Bassett Hounds, and 1 each of the following: Miniature Schnauzer, Border Terrier, Scottish Terrier, Pug, Cavalier King Charles Spaniel, Staffordshire Bull Terrier, Border Collie, Labrador Retriever, Flat Coat Retriever, Samoyed, Irish Water Spaniel, Irish Wolfhound, Red Setter, and St. Bernard. The remaining dog was a mixed-breed dog.

**Portovenogram grades**—Grades of portovenograms obtained during surgeries 1 and 2 were analyzed (Table 1). Compared with preocclusion portovenogram grades, there was a significant increase in portovenogram grade immediately following temporary complete single CPSS occlusion in surgery 1 (P < 0.001) and in surgery 2 (P = 0.014). In the 19 dogs that underwent the second attenuation procedure, there was a significant (P < 0.001) increase in preocclusion portovenogram grade between surgeries 1 and 2; similarly, there was a significant (P < 0.001) increase in postocclusion portovenogram grade between surgeries 1 and 2 (Figures 2 and 3).

**Anatomic features of the CPSSs**—Thirty-four of 45 (76%) dogs had a single extrahepatic CPSS, including portocaval shunts (27 dogs), gastrosplenic shunts (5 dogs), and portoazygous shunts (2 dogs). During surgery 1, median pre- and postocclusion portovenogram grades for these dogs were 1 (range, 1 to 4) and 4 (range, 1 to 4), respectively. Eleven (24%) of the dogs had a single intrahepatic portosystemic shunt, including central divisional shunts (3 dogs), patent ductus venosus (5 dogs), and a right divisional shunt (1 dog). During surgery 1, median pre- and postocclusion portovenogram grades for these dogs were 2 (range, 1 to 4) and 3 (range, 2 to 4), respectively. There was no significant difference in preocclusion portovenogram grades between dogs with intrahepatic shunts and dogs with extrahepatic shunts. Similarly, there was no significant difference in postocclusion portovenogram grades between dogs with intrahepatic shunts and dogs with extrahepatic shunts.

**Surgery**—For dogs that initially underwent partial attenuation of a single CPSS during surgery 1, the median pre- and postocclusion portovenogram grades during that procedure were 1 (range, 1 to 4) and 3 (range, 1 to 4), respectively. In comparison, the median pre- and postocclusion portovenogram grades during surgery 1 for dogs that initially underwent complete attenuation of a single CPSS during that procedure were significantly higher (3 [range, 1 to 4; P = 0.028] and 4 [range, 3 to 4; P < 0.001], respectively). Six of 9 dogs for which the preocclusion portovenogram grade was 4 during surgery 1 and 15 of 22 dogs for which the postocclusion portovenogram grade was 4 during surgery 1 subsequently underwent complete single CPSS attenuation.

For dogs that underwent partial single CPSS attenuation during surgery 2, the median pre- and postocclusion portovenogram grades were 2 (range, 1 to 3) and 3 (range, 3 to 4), respectively. For dogs that underwent complete single CPSS attenuation during surgery 2, the median pre- and postocclusion portovenogram grades were 4 (range, 1 to 4) and 4 (range, 3 to 4), respectively. Too few dogs underwent surgery 2 to adequately test the significance of these differences.

**Age and weight**—At surgery 1, a significant, moderate, positive correlation was found between age and preocclusion portovenogram grades (r = 0.320; P = 0.032) and between age and postocclusion portovenogram grades (r = 0.481; P = 0.001; Figure 4). In 20 of 29 dogs that were ≥ 8 months old, the postocclusion portovenogram grade during surgery 1 was 4; in 2 of 16 dogs that were < 8 months old, the postocclusion portovenogram grade during surgery 1 was 4. No significant correlation was found between either pre- or postocclusion portovenogram grade during surgery 1 and body weight.

**Medical treatment prior to surgery 1**—Appropriate medical treatment (administration of antimicrobials including ampicillin, metronidazole, or neomycin; administration of antiseizure medication including diazepam, phenobarbital, or potassium bromide; provision of a low-protein diet; and administration of lactulose) had been given to 39 of 45 dogs prior to surgery 1 to adequately test the significance of these differences. Among these 39 dogs, no clinical response to medical treatment was evident in 6 (15%), partial clinical response was evident in 21 (54%), and complete resolution of clinical signs was evident in 12 (31%). Response to medical treatment was not significantly related to either pre- or postocclusion portovenogram grade during surgery 1.

**Clinical signs**—Prior to surgery 1, clinical signs relating to a CPSS were reported in all 45 dogs. Median duration of signs was 3 months (range, 1 to 50 months). Forty (89%) dogs had neurologic signs including signs of depression, abnormal behaviors, head pressing, circling, ataxia, aimless wandering, insomnia, muscle tremors, seizures, blindness, deafness, and ptality. Thirty-three dogs (73%) had gastrointestinal tract signs including vomiting, diarrhea,

<p>| Table 1—Portovenogram grades assigned before and after temporary complete occlusion of a single CPSS during surgical procedures performed in affected dogs. |
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| Portovenogram grade | Surgery 1 (n = 45 dogs) | | Surgery 2 (n = 19 dogs) | |</p>
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inappetence, pica, and melena. Twenty-three dogs (51%) had urinary tract signs including polyuria with polydipsia, urate calculi with or without urethral obstruction, hematuria, and nocturia. Twenty-two (49%) dogs were subjectively considered to be small in stature as a result of poor growth. Ten (22%) dogs had other clinical signs including weakness, prolonged recovery from anesthesia, dyspnea, pyrexia, and cough. The median number of body systems clinically affected in the 45 dogs was 3 (range, 1 to 5).

During surgery 1, the median pre- and postocclusion portovenogram grades among the 40 dogs with neurologic signs were 1 (range, 1 to 4) and 3 (range, 1 to 4), respectively. In comparison, the median preocclusion portovenogram grade among the 5 dogs without neurologic signs was higher (median grade, 4; range, 1 to 4) although this difference was not significant ($P = 0.060$). All 5 dogs without neurologic signs had postocclusion portovenogram grades of 4; this grade was significantly ($P = 0.023$) higher than that of the neurologically affected dogs.

Records regarding clinical signs detected at follow-up examination after surgery 1 were available for 36 dogs. The median interval between surgery 1 and follow-up examination was 3 months (range, 1 to 13 months). Five (14%) dogs (4 that underwent partial single CPSS attenuation and 1 that underwent complete single CPSS attenuation) had a poor response to surgery with little if any clinical improvement. Twelve (33%) dogs (8 that underwent partial single CPSS attenuation and 4 that underwent complete single CPSS attenuation) had partial clinical improvement, but clinical signs of a portosystemic shunt were still present. Nineteen (53%) dogs (9 that underwent partial shunt attenuation and 10 that underwent complete shunt attenuation) had no remaining clinical signs. This subjective grading of clinical response to surgery 1 was not significantly correlated with either pre- or postocclusion portovenogram grade during surgery 1.

The median number of body systems that were clinically affected prior to surgery 1 was 3 (range, 1 to 5); at follow-up examination, the median number of affected systems was 0 (range, 0 to 4), which represented a significant ($P < 0.001$) decrease. Neurologic signs were still present in 7 (19%) dogs, poor growth in 4 (11%) dogs, gastrointestinal tract signs in 14 (39%) dogs, and urinary tract signs in 6 (17%) dogs. Compared with findings prior to surgery 1, the prevalence of each of these clinical signs was significantly ($P < 0.05$) lower. In addition, the number of clini-
postocclusion (r = -0.337; P = 0.037) portovenogram grades during surgery 1.

Portal pressure—Portal pressures were measured before and after temporary complete shunt occlusion during surgery 1 in 38 and 35 dogs, respectively. Median preocclusion portal pressure was 7 mm Hg (range, 0 to 21 mm Hg), and median postocclusion portal pressure was 11 mm Hg (range, 7 to 55 mm Hg). There was a moderate positive correlation between postocclusion portovenogram grade and preocclusion portal pressure (r = 0.390; P = 0.015).

Portal pressures were measured before and after temporary complete shunt occlusion during surgery 2 in 11 and 10 dogs, respectively. Median pre- and postocclusion portal pressures were 7 mm Hg (range, 2 to 11 mm Hg) and 13 mm Hg (range, 8 to 17 mm Hg) respectively. This set of data was too small to determine any correlations between portal pressures and portovenogram grades.

Surgical complications and survival—During surgery 1, intraoperative complications were reported for only 2 dogs. One dog had a central divisional intrahepatic shunt, and the other had a patent ductus venosus. Dissection of both of these shunts resulted in iatrogenic puncture of the diaphragm; punctures were closed via suture placement, and there were no reported sequelae.

Following surgery 1, short-term postoperative complications were reported for 19 of 45 (42%) dogs. Minor short-term complications included transient ascites with or without surgical wound discharge (6 dogs), mild self-limiting vomiting and diarrhea (4 dogs), surgical wound infection (2 dogs), and self-limiting sterile cystitis secondary to urate urolith removal at the time of CPSS attenuation (1 dog). Major short-term complications included septic peritonitis (1 dog), intermittent seizures (1 dog), status epilepticus (3 dogs), severe blood loss and anemia (2 dogs), and severe hemorrhagic gastroenteritis (3 dogs). Six (13%) dogs, including the 3 dogs with severe hemorrhagic gastroenteritis, 1 dog with severe blood loss, and 2 dogs with status epilepticus, died. There was no apparent association between pre- or postocclusion portovenogram grades during surgery 1 and the incidence of surgical complications or death.

Following surgery 2, 5 dogs had minor short-term complications and all dogs survived through the immediate postoperative period to suture removal. The minor short-term complications included ascites (2 dogs), hemorrhage from the surgical wound resulting in anemia (1 dog), hemorrhage from an ovarian stump secondary to concomitant ovariectomy (1 dog), undefined surgical wound complications (1 dog), and skin burn secondary to application of a warming bag (1 dog).

Discussion

Intraoperative mesenteric portovenography has been used to assess immediate changes in blood flow through intrahepatic portal vessels following attenuation of a single CPSS in dogs. The findings of the present study have indicated that IMP can also be used to monitor gradual changes in intrahepatic portal blood flow during the months following single CPSS attenu-
ation. Moreover, in dogs undergoing single CPSS attenuation, significant correlations were detected between the degree of opacification of intrahepatic portal vessels during the surgery (surgery 1) and age, presence of neurologic signs before surgery, number of body systems that were clinically affected at follow-up examination, and follow-up preprandial serum bile acids concentration. Therefore, results of IMP during surgery 1 may help veterinarians to predict which dogs will respond well to attenuation of a single CPSS. Further studies are necessary to relate changes in intrahepatic portal blood flow with histopathologic findings, thereby improving our understanding of hepatic recovery following shunt attenuation.

The portovenogram grading system used in the present study has not been previously described, to our knowledge. We chose not to use a previously published grading method because those methods have been associated with a number of shortcomings. Moreover, the association of data obtained by use of those grading systems with clinical outcome has not been determined.

For each dog included in our study, IMP involved acquisition of a dynamic series of portovenograms, which enabled us to select images of the intrahepatic portal vessels at peak opacification for analysis. Portovenograms were graded according to the number of branch generations of intrahepatic portal vessels that were visible because it was assumed that this reflects the degree of development of the intrahepatic portal vasculature. The degree of opacification of the hepatic parenchyma was not assessed because that opacification represents the phase of the portovenographic procedure in which contrast medium is moving out of the portal vessels. We also chose not to consider the area or distribution of intrahepatic portal vasculature opacification. Thus, portovenograms in which the distribution of portal blood flow among liver lobes appeared markedly uneven were assessed in the same manner as portovenograms in which the distribution appeared more uniform; grades were assigned on the basis of appearance of the intrahepatic portal vessels that were visible, regardless of portal blood flow distribution. In healthy dogs, the liver has a large, redundant volume, permitting successful resection of 70% of liver mass; therefore, normal portal vasculature in 30% of the liver should be sufficient for liver regeneration regardless of its lobar distribution.

In the present study, opacification of the intrahepatic portal vasculature increased significantly in dogs with a single CPSS immediately after temporary complete CPSS occlusion. Therefore, preocclusion portovenograms reflected intrahepatic portal blood flow in the presence of a patent CPSS, whereas postocclusion portovenograms represented anatomic features of the preexisting intrahepatic portal vasculature. Our study also revealed an increase in opacification of the intrahepatic portal vasculature in dogs 2 to 13 months after CPSS attenuation. This increase most likely represented development of hypoplastic portal vasculature following exposure to increased blood flow. Such development may be attributable to a number of factors including opening of preexisting blood vessels and angiogenesis. This is an important finding, which, to the authors’ knowledge, has not been previously reported. Previously, development of the intrahepatic portal vasculature has been inferred from a gradual decrease in shunt fraction and an improvement in biochemical parameters of liver function following CPSS attenuation.

Opacification of the intrahepatic portal vasculature both before and after temporary shunt occlusion was greater in dogs that underwent complete single CPSS attenuation than in dogs that underwent partial single CPSS attenuation. A similar finding has been previously reported. It has also been reported that dogs that tolerate complete CPSS attenuation have better long-term clinical and biochemical outcomes, compared with outcomes for dogs that tolerate only partial CPSS attenuation. Together, these findings suggest that dogs with a CPSS and hypoplasia of the intrahepatic portal vasculature may have a poorer outcome following surgical CPSS attenuation, compared with CPSS-affected dogs with more developed intrahepatic portal vasculature. This hypothesis is supported by the finding in the present study that certain variables of long-term outcome following attenuation of a single CPSS in dogs were significantly correlated with either pre- or postocclusion portovenogram grade during surgery 1.

In dogs with a single CPSS, age was positively correlated with pre- and postocclusion portovenogram grades. This suggests that dogs undergoing surgery at an older age have a lower shunt fraction and more developed intrahepatic portal vasculature, compared with dogs undergoing surgery at a younger age. This seems logical; intrahepatic portal blood flow was probably sufficient to prevent signs of reduced liver function in early life among those dogs with CPSSs that become clinically affected at an older age. However, previous studies have not revealed any association, particularly a negative association, between age and long-term clinical outcome following CPSS attenuation. So although older dogs may have a more developed intrahepatic portal vasculature and be more tolerant to CPSS attenuation in the short-term, the process of long-term hepatocyte recovery may be independent of age.

In the present study, all dogs without neurologic signs had a well-developed intrahepatic portal vasculature. This finding is in agreement with those of a previous study, which indicated that dogs without preoperative encephalopathy are more tolerant of complete CPSS attenuation and have fewer complications after CPSS attenuation, compared with dogs with preoperative encephalopathy.

A positive association was identified between preocclusion portal pressure and postocclusion portovenogram grade in CPSS-affected dogs. This association cannot be explained on the basis of the data presented in the present study. Portal pressures may be lower (0 to 9 mm Hg) in dogs with a CPSS, compared with values in clinically normal dogs (6 to 10 mm Hg), presumably because of low vascular resistance afforded by a wide-diameter portosystemic shunt. Therefore, among dogs with a CPSS, a higher and thus more normal portal pressure may be consistent with a lower shunt fraction and...
more developed intrahepatic portal vasculature. Further studies of the control of portal pressure in clinically normal dogs, and dogs with portosystemic shunts would be required to refute or substantiate this proposal.

Our study was limited by the number of dogs included. However, the study results are valuable because many of the significant correlations identified were associated with values of $P \leq 0.001$. Moreover, to the authors’ knowledge, this is only the second study to investigate the relationship between results of portovenography and surgical success in a group of dogs with a single CPSS. Acquisition of data from more CPSS-affected dogs for analysis may enable additional correlations between the results of portovenography and surgical success to be determined and allow identification of specific numerical predictors of clinical outcome. The effect of duration and type of medical treatments used following surgical CPSS attenuation was not assessed in this study. Medical treatments may have affected long-term outcomes in the study dogs.

Our data suggest that IMP can be used to assess immediate and long-term changes in intrahepatic portal blood flow in dogs undergoing partial or complete attenuation of a single CPSS. The degree of opacification of intrahepatic portal vessels was correlated negatively with preprandial serum bile acids concentrations at follow-up examination and positively with long-term clinical outcome. Therefore, it appears that IMP can be used to help predict outcome following surgical treatment of single CPSSs in dogs.

References


