In dogs that have undergone surgery for correction of a congenital PSS, multiple factors have been found to be associated with outcome, including development of postoperative complications, results of serum biochemical testing, and portal pressure. To our knowledge, however, no preoperative factors have been found to be significantly associated with long-term outcome following surgery, making it difficult to advise owners on prognosis prior to surgery. Previous authors have suggested that long-term medical management of PSS may result in hepatic failure because medical management will not slow the progressive atrophy and fibrosis associated with this condition. In addition, PSSs have been associated with characteristic hepatic histologic abnormalities, including lobular atrophy, arteriolar hyperplasia, and lipogranulomas. Occasionally, biliary hyperplasia, sinusoidal dilatation, fibrosis, cell swelling, lipidosis, and inflammatory cell infiltration may also be present. Lobular atrophy and arteriolar hyperplasia are thought to develop secondary to decreased hepatic blood flow and decreased concentrations of hepatotrophic factors, and lipogranulomas are thought to be the remnants of degenerated lipid-filled hepatocytes. Biliary hyperplasia may represent nonspecific trophic stimulation, sinusoidal dilatation may be an adaptation to the lack of normal portal venous perfusion, fibrosis may represent additional damage associated with attenuated blood flow, and lipidosis may develop as a result of the lack of hepatocyte nutrition. The most severe changes are believed to be biliary hyperplasia, fibrosis, and necrosis.

Because progression of hepatic histologic abnormalities over time in dogs with congenital PSSs may lead to liver failure, it seems plausible that the severity of histologic abnormalities prior to surgery could be used to predict long-term outcome. The purpose of the study reported here, therefore, was to determine whether results of histologic examination of hepatic biopsy samples could be used as an indicator of long-term outcome in dogs undergoing surgical correction of a congenital PSS.

**Materials and Methods**

**Case selection criteria**—Medical records of all dogs that underwent exploratory laparotomy for a congenital PSS between October 1997 and August 2005 at...
the Colorado State University Veterinary Medical Center were reviewed. Dogs were included in the study if histologic slides of hepatic biopsy samples obtained at the time of surgery were available for review. Dogs with concurrent diseases at the time of surgery were excluded from the study.

**Medical records review**—Data obtained from the medical records of dogs included in the study consisted of breed, sex, age at the time of surgery, location of the shunt (intrahepatic vs extrahepatic), and survival time. If survival time could not be obtained from the medical record, the referring veterinarian or owner was contacted by telephone. For dogs that had died, cause of death was considered to be related to the PSS if there was evidence of a recurrence of clinical signs, particularly signs of hepatic encephalopathy or hepatic failure.

**Review of histologic slides**—All H&E-stained histologic slides of hepatic biopsy samples obtained at the time of surgery were reviewed by a single individual (BEP) blinded to survival time, and severity of histologic abnormalities was graded. Slides were specifically evaluated for the severity of arteriolar hyperplasia, biliary hyperplasia, fibrosis, cell swelling, lipoidosis, lymphoplasmacytic cholangiohepatitis, suppurative cholangiohepatitis, lipid granulomas, and dilated sinusoids. Each histologic feature was graded on a scale from 0 to 3, with 0 indicating that the feature was absent, 1 indicating minimal changes, 2 indicating moderate changes, and 3 indicating severe changes. A total score was also calculated by adding scores for each individual feature.

**Statistical analysis**—Data were summarized as median and range. For each histologic feature, a univariate Cox proportional hazards regression model was used to evaluate whether histologic grade was associated with survival time. Kaplan-Meier survival analysis was used to determine overall survival time, with survival time calculated as time from surgery to death from disease. Patients were censored at the time of the last contact if they were alive, were lost to follow-up, or died of unrelated causes. All analyses were performed with standard software. Values of \( P < 0.05 \) were considered significant.

**Results**

Sixty-four dogs met the criteria for inclusion in the study. No dogs examined during the study period were excluded because of concurrent disease.

Of the 64 dogs included in the study, 29 were male and 35 were female. Median age at the time of surgery was 6.4 months (range, 2 to 108 months), with 53 dogs < 2 years old and 11 dogs > 2 years old at the time of surgery. Thirty-nine (61%) dogs had extrahepatic shunts, and 25 (39%) had intrahepatic shunts. Dogs with extrahepatic shunts included 11 Yorkshire Terriers, 5 Miniature Schnauzers, 3 Dachshunds, 3 mixed-breed dogs, 2 English Bulldogs, 2 Maltese, and 13 dogs representing 8 other breeds (Australian Shepherd, Bernese Mountain Dog, Border Collie, Greyhound, Jack Russell Terrier, Bullmastiff, Old English Sheepdog, and Irish Wolfhound). Dogs with intrahepatic shunts included 7 Labrador Retrievers, 4 mixed-breed dogs, 3 German Shepherd Dogs, 3 Golden Retrievers, and 8 dogs representing 8 other breeds (Australian Shepherd, Bernese Mountain Dog, Border Collie, Greyhound, Jack Russell Terrier, Bullmastiff, Old English Sheepdog, and Irish Wolfhound).

Surgical procedures varied and included cellophane banding (38 dogs with extrahepatic shunts and 6 with intrahepatic shunts), suture placement (9 dogs with extrahepatic shunts), cellophane banding in combination with suture placement (5 dogs with intrahepatic shunts), partial attenuation with mattress sutures (3 dogs with intrahepatic shunts), amniotic constriction placement (1 dog with an intrahepatic shunt), extrahepatic graft placement (1 dog with an intrahepatic shunt), and abdominal exploration alone (1 dog with an extrahepatic shunt with portal vein aplasia). The shunt was partially attenuated at the time of surgery in 24 dogs and was not attenuated at the time of surgery in 33. The degree of attenuation at the time of surgery was not known for 6 dogs.

Thirty-eight (29 with extrahepatic shunts and 9 with intrahepatic shunts) of the 64 (59%) dogs were alive at the time of final follow-up; median follow-up time for these dogs was 51.7 months (range, 15.6 to 74.5 months). Fifteen (23%) dogs had died of causes associated with the PSS, including 4 dogs (3 with extrahepatic shunts and 1 with an intrahepatic shunt) that died in the immediate postoperative period. Median survival time for the 4 dogs that died in the immediate postoperative period was 1 day (range, 0 to 9 days). Median survival time for the other 11 dogs that died of causes associated with the PSS was 7.9 months (range, 1.4 to 28 months). Three (5%) dogs (1 with an extrahepatic shunt and 2 with an intrahepatic shunt) died of unrelated causes; survival times were 64, 71, and 87 months. Eight (13%) dogs (4 with extrahepatic shunts and 4 with intrahepatic shunts) were lost to follow-up; median follow-up time was 8 months (range, 0.06 to 46 months). Overall, there was a median follow-up time of 35.7 months (range, 0 to 86.6 months).

Median overall survival time was 50.6 months (Figure 1), and 1-, 2-, and 3-year survival rates were 93%, 79%, and 29%, respectively. Median survival time for dogs with extrahepatic shunts (52.7 months; range, 0 to 70.3 months) was not significantly (\( P > 0.3 \) dif-
Different from median survival time for dogs with intrahepatic shunts (45.7 months; range, 0 to 86.6 months). None of the histologic features that were examined were found to be significantly associated with survival time (Table 1). In addition, the total histologic score (median, 6; range, 1 to 12) was not significantly (P = 0.91) associated with survival time (hazard ratio, 1.01; 95% confidence interval, 0.85 to 1.18). Total histologic score for dogs with an extrahepatic shunt (median, 5; range, 1 to 11) was not significantly (P = 0.41) different from total score for dogs with an intrahepatic shunt (median, 6; range, 3 to 12). In addition, fibrosis score and total histologic score were not significantly different between dogs < 2 years old at the time of surgery and dogs > 2 years old at the time of surgery (P = 0.43 and 0.18, respectively).

Discussion

Results of the present study suggested that in dogs undergoing surgical correction of a PSS, severity of hepatic histologic abnormalities at the time of surgery was not significantly associated with survival time. Thus, severity of hepatic histologic lesions could not be used to determine prognosis for dogs with PSS prior to surgery.

Sex, age, and breed distributions of dogs in the present study were similar to distributions for dogs in previous studies of PSSs. Thirty-nine of the 64 (61%) dogs had an extrahepatic shunt and 25 (39%) had an intrahepatic shunt, whereas, by comparison, 68% to 90% of dogs in previous studies had an extrahepatic shunt and only 10% to 32% had an intrahepatic shunt. This difference in distribution of shunt location could have an effect on our results, as the site of liver biopsy could have been affected, particularly in dogs with intrahepatic shunts. The severity of hepatic histologic lesions in dogs with PSS is believed to be related to the degree of shunting and may vary among liver lobes, especially in dogs with intrahepatic shunts. On the other hand, a previous study reported that histologic lesions were only slightly more severe in the affected hepatic lobe than in the other hepatic lobes in 5 of 11 dogs with intrahepatic shunts and that hepatic lesions were uniform in dogs with extrahepatic PSSs.

The immediate postoperative mortality rate in the present study (4/64 [6%]) was similar to rates reported in other studies. However, the immediate postoperative mortality rate for dogs with extrahepatic shunts was 7.7% (3/39), whereas the rate for dogs with intrahepatic shunts was only 4% (1/23). By comparison, immediate postoperative mortality rates in previous studies involving dogs with intrahepatic shunts were 27%, 23%, and 20%. A possible explanation for this difference is that surgical techniques differed between studies.

Typical hepatic histologic features that have previously been associated with PSSs were evaluated in the present study. Importantly, neither fibrosis nor biliary hyperplasia, two of the features considered to be the most important histologic findings, was associated with survival time. However, none of the dogs in the present study had grade 3 fibrosis or biliary hyperplasia, even though 11 dogs were > 2 years old at the time of surgery. This finding may support the suggestion that age is not a reliable predictor of postoperative death or complications.

Histologic lesions in dogs with PSS have been reported to be reversible if the shunt is attenuated or ligated. A previous study for instance, reported a 44% reduction in severity of hepatocellular degeneration following partial ligation. The reduction in hepatocellular degeneration was postulated to be due to an increase in blood flow and, hence, an increase in the concentration of hepatotrophic factors. Hepatic fibrosis also diminished in 8 of 25 dogs evaluated before and after partial ligation of the shunting vessel. The extent of the reversibility of histologic lesions is likely related to the severity of the initial lesions. In the present study, the reversibility of the hepatic lesions was not evaluated. In addition, because only 17 dogs in the present study had grade 3 lesions, we were not able to assess the effect of severe histologic lesions on outcome.

It is possible that some dogs in the present study that did not have a favorable long-term outcome had microvascular dysplasia in addition to a PSS. The histologic features of microvascular dysplasia are similar to those seen with PSSs and additional diagnostic testing, such as nuclear scintigraphy or portovenography, is needed to differentiate the two conditions. Unfortunately, none of the dogs that died or were euthanatized in the present study because of a recurrence of clinical signs related to PSS underwent nuclear scintigraphy to determine whether they also had microvascular dysplasia.
Limitations of the present study include its retrospective nature, the fact that some dogs were lost to follow-up, and the fact that some dogs were euthanized at the owners’ request. Dogs that were euthanized were classified as having died of causes related to the PSS, and this may have included some dogs that only occasionally had signs associated with the PSS. Willingness to continue with medical management and to tolerate clinical signs associated with PSS can vary among owners, and this may have affected survival times.

References