Use of transcolonic portal scintigraphy to monitor blood flow and progressive postoperative attenuation of partially ligated single extrahepatic portosystemic shunts in dogs

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Summary: Transcolonic portal scintigraphy was used to evaluate immediate and long-term changes in shunt blood flow after partial ligation of single extrahepatic portosystemic shunts in 8 dogs. Scintigraphy was performed before surgery, within the first 7 days after surgery, and 3 to 9 months after surgery. Shunt fraction values for this group of dogs before surgery ranged from 67 to 87% (normal reference range, ≤ 15%). On the basis of postoperative scintigraphy, 4 dogs had immediate and lasting occlusion of shunt blood flow (shunt fraction, ≤ 15%). One dog had a shunt fraction value within the reference range immediately after surgery, had evidence of recurrent shunt blood flow (shunt fraction, 23%) at 3 months after surgery, and again had a shunt fraction value within the reference range 9 months after surgery. Persistent, though reduced, shunt blood flow (shunt fractions, 23 and 27%) was evident immediately after surgery in 2 dogs. One of these dogs had a shunt fraction within the reference range 3 months after surgery, whereas shunt blood flow in the other dog had increased to 41%. One dog had no appreciable change in shunt blood flow immediately after surgery (shunt fraction, 70%), but the shunt fraction value had decreased to 41% at the time of the final scintigraphic examination.

As assessed by transcolonic portal scintigraphy, partial single extrahepatic portosystemic ligation caused a significant decrease in mean shunt blood flow in this group of 8 dogs and resulted in eventual shunt occlusion in a majority of the dogs (6 of 8 dogs). Partial ligation with progressive attenuation of shunt blood flow may obviate the need to perform additional surgery.

Single extrahepatic portosystemic shunts (SEHS) are anomalous blood vessels connecting the portal venous and systemic venous circulation.1-3 The pathophysiology, diagnosis, and treatment of SEHS have been extensively documented.1-8 To the best of our knowledge, the temporal changes that develop in postoperative shunt blood flow after one-stage surgical attenuation (partial ligation) have not been reported.

Animals with SEHS may be managed medically for short periods; however, most of these animals eventually need surgical intervention to alleviate clinical signs associated with this condition.1,3,8-10 Surgical management of SEHS consists of partial or complete ligation of the shunt vessel at a location closest to the systemic venous circulation. The decision to completely or partially ligate the shunt is made on the basis of intraoperative evaluation of changes in systemic arterial blood pressure, portal venous pressure, and the degree of gastrointestinal splanchnic venous congestion.1,1,6-1,11,12 Adverse sequelae to excessive attenuation of the shunt can develop during or up to several days after surgery. Intraoperative complications of excessive attenuation include systemic hypotension, splanchnic venous congestion, and portal hypertension. Increased resistance to hepatic blood flow and portal venous circulation has been documented in some dogs with congenital shunts and may lead to acute severe portal hypertension 6 to 24 hours after surgery.1,12 Acute severe portal hypertension is characterized by signs of acute abdominal pain, hemorrhagic diarrhea, hypovolemic shock, septic shock, and death.1,3,11 These animals require emergency surgery to remove the ligature. Signs of less severe portal hypertension, such as ascites, may develop hours to days after complete or partial shunt ligation.1,11,13

Although the reliability of intraoperative assessment of hemodynamic measurements can potentially be compromised by the use of general anesthesia, surgical manipulation, and hypoproteinemia, hemodynamic monitoring to determine the optimal amount of attenuation that can be tolerated is an accepted method to reduce intraoperative or
postoperative complications. If during attenuation, the systemic arterial blood pressure decreases rapidly, the portal pressure exceeds a predetermined value, or there is evidence of splanchic venous congestion, then the ligature should be released and the shunt carefully reattenuated to avoid local and systemic complications. Staged attenuation of SEHS has been recommended as an alternative strategy to reduce the development of severe postoperative portal hypertension. The disadvantages of staged attenuation are repeated surgeries (which are technically more difficult because of adhesions around the shunt vessels), repeated anesthetic risks, and additional costs.

It is possible that partially ligated shunts may undergo progressive attenuation through natural processes associated with manipulation of the shunt vessel during surgery and acute and chronic inflammatory responses to the silk sutures. Assuming occlusion develops subsequent to partial ligation in most dogs, a conservative initial surgical approach could be adopted, which should result in lower morbidity and mortality. Staged attenuation could be reserved for dogs that have signs of persistent portosystemic shunting. Transcolonic 99mTc-pertechnetate portal scintigraphy is a noninvasive, reliable diagnostic method to determine the presence or absence of a shunt. Additionally, shunt fraction values can be calculated to provide a quantitative estimate of shunt blood flow. The study reported here was undertaken to determine the fate of partially ligated SEHS by use of transcolonic portal scintigraphy for evaluation of shunt blood flow before and after surgery.

**Materials and Methods**

Dogs referred with clinical signs consistent with portosystemic shunting were evaluated for inclusion in this study. A complete physical examination was performed prior to transcolonic portal scintigraphy. Scintigraphy was performed without the use of chemical restraint. Standard procedures for radioisotope administration, image acquisition, and data processing were used. Enemas were not performed prior to radioisotope administration. Shunt fraction values were calculated according to a previously reported protocol. Reference range of shunt fraction values for clinically normal dogs was considered to be ≤ 15%. A serum biochemical analysis, CBC, and blood crossmatching were performed before surgery. Preanesthetic medications given to the dogs consisted of meperidine, oxymorphone, or ketamine. Induction and maintenance of anesthesia was accomplished with isoflurane in oxygen. The heart rate and rhythm, esophageal temperature, direct arterial blood pressure, and portal venous blood pressure were monitored in all dogs.

Surgery was performed via a standard midline approach. A small catheter was placed into a splenic, mesenteric, or portal vein to measure portal pressure. After the shunt vessel was isolated, it was temporarily occluded to determine the ability of the hepatopetal circulation to tolerate total ligation. If during occlusion, the mean systemic arterial pressure decreased more than 10 mm of Hg, the portal pressure exceeded 14 mm of Hg, or splanchic congestion was observed, then partial ligation was performed. The 3-0 silk ligature was tightened with the intention of avoiding local and systemic hemodynamic changes. The abdomen was closed in a routine manner and dogs were monitored for postoperative signs of portal hypertension.

To evaluate the immediate effect of ligation, scintigraphy was performed on each dog within 1 week after surgery. To evaluate the long-term effects of ligation, additional scintigraphic examinations were performed 3 to 9 months after surgery. Shunt fraction values before and after surgery were compared by use of the Wilcoxon's signed rank test to evaluate changes in mean shunt blood flow.

**Results**

Three males and 5 females between 6 months and 3 years of age at time of initial admittance were included in this study. All were small-breed dogs and included 4 Yorkshire Terriers, 1 Miniature Schnauzer, 1 Miniature Dachshund, 1 Papillon, and 1 Cairn Terrier. Laboratory values were indicative of portosystemic shunting in most dogs. Diagnosis of a portosystemic shunt was made by use of transcolonic portal scintigraphy. Preoperative scintigraphy in all 8 dogs was characterized by detection of radioisotope activity in the heart prior to detection of activity in the liver. Preoperative shunt fraction values ranged from 67 to 87%, with a mean (± SD) shunt fraction value of 76 ± 5.95% (Table 1).

All dogs recovered from partial ligation without observable signs of portal hypertension. Initial postoperative scintigraphy performed within 7 days of surgery indicated that 5 of the dogs had shunt fraction values within the reference range (≤ 15%), 2 dogs had persistent, though reduced, shunt blood flow (shunt fractions, 23 and 27%), and 1 dog had little change in shunt blood flow (shunt fraction, 58%).
70%). Shunt fraction values 1 week after surgery ranged from 8 to 70% with a mean (± SD) value of 21.87 ± 20.57% and was significantly (P = 0.012) decreased relative to preoperative values.

All owners reported decreases in or cessation of previously observed clinical signs associated with portosystemic shunting. Final postoperative scintigraphy performed 3 to 9 months after surgery determined 6 dogs had shunt fraction values within the reference range. Shunt fraction values in the remaining 2 dogs were reduced relative to preoperative values (shunt fractions, 28 and 41%). Shunt fraction values 3 to 9 months after surgery ranged from 8 to 41% with a mean (± SD) value of 16.12 ± 11.97% and were significantly (P = 0.012) decreased relative to preoperative values, but were not significantly different than the immediate postoperative values.

Discussion

Objectives to consider while determining the degree of initial attenuation during surgical ligation of SEHs are the desire to create sufficient reduction of shunt blood flow to alleviate clinical signs and the desire to minimize peracute to subacute postoperative complications that can develop following excessive ligation.1,3,5,6,8,11,12,21 A conservative approach to ligation would be expected to lead to fewer complications, but insufficient attenuation may initially fail to achieve sufficient portal blood flow through the liver to reestablish normal metabolic function. However, if partial shunt ligation results in progressive reduction of the shunt blood flow in most dogs, a strategy of conservative initial shunt attenuation would represent a rational approach for safe and effective treatment of SEHs. Multiple staged surgeries would be restricted to dogs with persistent clinical signs, laboratory evidence of hepatic dysfunction, and scintigraphic evidence of a patent shunt. We evaluated changes in shunt blood flow within 1 week and 3 to 9 months after surgery, seeking evidence that progressive reduction in shunt blood flow (presumably associated with progressive increase in shunt vessel resistance or progressive decrease in hepatic vascular resistance) developed after partial shunt ligation.

Transcolonic nuclear scintigraphy is an accurate test to diagnose portosystemic shunts.17,18,22 Alternate techniques to diagnose portosystemic shunting are available and include angiography, splenoportography, intraoperative portography, identification during surgery, ultrasonography, and magnetic resonance imaging.1,3,8,10,11,23-27 We chose transcolonic 99mTc-pertechnetate scintigraphy because it represented an available, noninvasive method to detect portosystemic shunts and to quantitate relative shunt blood flow.19,20 The method used to calculate shunt fraction values has been shown to yield valid estimates of shunt blood flow although accuracy declines with very large (> 90%) and very small (< 5%) shunts.19,20 Background activity (counts originating from tissues surrounding the heart and liver) and cross-talk (liver activity recorded in a heart region of interest) cause calculated shunt fraction values in clinically normal dogs to be > 0. The upper range for shunt fraction values of clinically normal dogs will probably vary from institution to institution, as there is variability in the definition of liver and heart regions of interest. A previous report has suggested that shunt fraction values of < 10 to 15% should be considered normal.20 We chose the higher value on the basis of our clinical experience. We have observed that shunt fraction values are higher in clinically normal small-breed dogs, which represent most of the dogs referred for evaluation of suspected portosystemic shunting.

The maximal tolerated portal pressure during shunt ligation in this study was 14 mm of Hg, which was a conservative value compared with most published reports,1,12 but is the current standard we use to minimize the rate of postoperative complications.

Factors other than the mechanical occlusion of the vessel by the ligature may affect shunt blood flow. Manipulation and handling of the vessel during surgery may cause postoperative swelling of the vessel wall and vasospasm, resulting in decreased shunt blood flow for a variable period after surgery. This could explain that, despite evidence of intraoperative shunt patency, dogs 1 to 5 had shunt fraction values within the reference range on scintigraphy performed within 1 week after surgery. Swelling and vasospasm would be expected to have only a transient effect on shunt blood flow, which may explain why dogs 5 and 8 had larger shunt fraction values on scintigraphy performed 3 to 9 months after surgery relative to values observed immediately after surgery.

Silk ligatures induce an inflammatory reaction within the vessel wall. Silk binds γ-globulin, which then binds complement and causes an acute inflammatory reaction characterized by chemotaxis of neutrophils, degranulation, hydrolytic enzyme release, and tissue necrosis.13 The initial inflammatory response lasts 5 to 7 days after ligation placement, and the ensuing fibroblast infiltration, proliferation, and eventual scar formation usually is complete within 10 to 15 days after suture placement.9,13,15 This local response results in narrowing of vessel diameter and, in conjunction with vessel thrombosis that may develop at any time after vessel ligation, could result in occlusion of the vessel. Scar formation and venous thrombosis probably were responsible for the progressive reduction in shunt blood flow observed in dogs 6 and 7 and for the apparent occlusion of shunt blood flow observed on long-term follow-up scans in dogs 1 to 6.

Results of scintigraphy on dogs 5 and 8 were indicative of increased shunt blood flow between the time of the initial postoperative scan and the subsequent follow-up scan. It is possible that in
these 2 dogs the initial postoperative scan reflected transient increased attenuation associated with vasospasm or the acute inflammatory response, whereas the follow-up scintigraphy was performed during periods of subsiding inflammation and increased lumen diameter. One of these 2 dogs (dog 5) had additional follow-up scintigraphy 6 months later that did not reveal evidence of a patent shunt. We theorized that in this dog scar formation or venous thrombosis caused progressive vessel obstruction and eventual occlusion.

Changes in shunt fraction values following partial ligation of extrahepatic shunts will depend on vascular resistance to blood flow through the shunt vessel vs resistance to blood flow through the liver. We assumed that hepatic vascular resistance was increased at the time of surgery, because portal pressure in each dog was abnormally high after shunt ligation. Improved delivery of hepatotrophic factors promotes hepatic regeneration and prevents signs of hepatomegaly in dogs with experimental portosystemic diversions.2,3,5 The mode of action and effect on hepatic circulation attributed to these hepatotrophic factors have not been completely elucidated and are controversial.5

Regardless of the factors involved, we believed hepatic vascular resistance did decrease over time in dogs that had shunt fraction values within the reference range on follow-up scans. In our opinion, the fact that shunt fraction values were within the reference range also indicated that multiple extrahepatic shunts had not developed. We found no other clinical evidence of chronic portal hypertension, such as ascites, in these dogs. It was, however, unlikely that a decrease in hepatic vascular resistance alone could explain reference range shunt fraction values in these dogs. Daniel et al2 reported that very high shunt fraction values (> 90%) developed in most of their experimental dogs following creation of portosystemic fistulas. Presumably, these experimental dogs had typical hepatic vascular resistance. We concluded that the dogs in our study with postoperative shunt fraction values ≤ 15% developed shunt occlusion, and that progressive partial occlusion was an important factor in the reduction of shunt fraction values observed in the remaining dogs. We also believed that persistent increased hepatic vascular resistance probably played a role in the maintenance of shunt blood flow in the 2 dogs with shunt fraction values higher than the reference range on long-term follow-up scintigraphic scans. Scintigraphy cannot differentiate between persistent shunt blood flow through the original shunt vessel vs shunt blood flow through new collateral portosystemic channels. We have observed the development of multiple extrahepatic shunts in a small number of dogs following ligation of single extrahepatic shunts. In our experience, dogs can become clinically normal despite scintigraphic evidence of persistent portosystemic shunting.

Our results indicated that the prognosis for immediate and permanent occlusion of shunt blood flow, or progressive decrease in shunt blood flow, was good in most dogs in which partial shunt ligation was performed. Further investigation of planned one-time partial ligation for the surgical management of SHS is justified, as major questions remain unanswered. Currently, reliable methods are not available at the time of the initial surgery to predict long-term outcome after partial shunt ligation. Reliable, noninvasive methods are not available to determine the cause of failure in dogs that do not achieve an optimal clinical result after the initial surgery. Presumably, failure develops because of insufficient attenuation of the original shunt vessel or because of development of multiple extrahepatic shunts. The ability to differentiate these conditions would impact the decision to attempt subsequent surgical interventions. We also lack a method to determine the minimal amount of hepatic portal blood flow that is necessary to support normal hepatic function in dogs.

References


