Intravascular Occlusion for the Correction of Extrahepatic Portosystemic Shunts in Dogs

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Background: Congenital extrahepatic portosystemic shunts (EHPSS) are common in dogs. An effective minimally invasive technique for correction of EHPSS could result in reduced morbidity, reduced costs, and reduced hospitalization times.

Hypothesis: Use of an intravascular occlusion device can effectively and safely result in acute complete occlusion of EHPSS in dogs.

Animals: Seven dogs with naturally occurring EHPSS that presented to the Purdue University Veterinary Teaching Hospital.

Methods: Prospective, clinical trial. The 7 dogs were consecutively enrolled over a 2-year period. Results of serum biochemistry, total serum bile acids, fasting plasma ammonia, abdominal radiography, and ultrasonography suggested the diagnosis of portosystemic shunts in all dogs. Definitive diagnosis of EHPSS was achieved with cranial mesenteric arterial portography and acute occlusion was attempted by the deployment of the Amplatzer vascular plug (AVP).

Results: EHPSS were identified in all dogs consisting of 5 portocaval and 2 portoazygous variants; 1/7 dogs (14%) were intolerant to temporary complete occlusion of the EHPSS. Of the remaining 6 dogs, 5 (83%) had complete occlusion of the EHPSS by the AVP. There were no complications and resolution of abnormal clinical signs and laboratory values was achieved in 4/5 (80%) dogs with complete occlusion.

Conclusions and Clinical Importance: Intravascular correction of EHPSS by the AVP is a viable option to surgical correction while larger studies will be required to determine the clinical applicability of this procedure in the broader portosystemic shunt population.

Key words: Canine; Congenital; Liver; Portography.

Extrahepatic portosystemic shunts (EHPSS) are common congenital vascular anomalies in dogs. These congenital defects are often suspected in young dogs presenting with variable clinical signs consistent with hepatic encephalopathy (HE) or hepatic insufficiency including lethargy, long anesthetic recovery times, and lower urinary tract signs associated with urate cystoliths.

Traditional management for EHPSS has included both medical and surgical treatments. Medical management reduces the clinical signs of HE and includes administration of antibiotics, and lactulose, and feeding low protein diets. However, medical management has been associated with a worse long-term prognosis in some dogs, while surgical correction is considered the definitive treatment for EHPSS. Complete acute vascular occlusion cannot be achieved in all dogs because of the development of severe portal hypertension. This necessitates only partial attenuation of the shunt, which may result in persistence of clinical signs. Because of this limitation in some dogs, gradual shunt occlusion techniques, allowing the portal system to adapt to increases in blood flow, have become the most common approach to EHPSS correction.

Minimally invasive vascular interventional techniques have been explored in many conditions in an effort to lower periprocedural morbidity and mortality. Additionally, these techniques may provide options for those animals with nonsurgical conditions or to owners who are reluctant to pursue surgery. Vascular embolization coils have been used to treat PSS but these have focused on intrahepatic portosystemic shunts. Our hypothesis was that deployment of the Amplatzer vascular plug (AVP) would be an effective and safe technique for complete acute correction of EHPSS in dogs.

Abbreviations:

- ABP: systemic arterial blood pressure
- AVP: Amplatzer vascular plug
- CdVC: caudal vena cava
- CMAP: cranial mesenteric arterial portography
- CVP: central venous pressure
- EHPSS: congenital extrahepatic portosystemic shunt
- FR: flow restrictor
- HE: hepatic encephalopathy
- MVP: mesenteric venous pressure

In blood flow, have become the most common approach to EHPSS correction.

Materials and Methods

Animals

Seven client-owned dogs presented to the Purdue University Veterinary Teaching Hospital (PUVTH) from January 2007 through January 2009 with a presumptive diagnosis of EHPSS. Presenting clinical signs included variable neurologic signs consistent with HE (7), lethargy (4), polyuria/polydypsia (2), vomiting (2), diarrhea (1), inappetance (1), ptalism (1), and stranguria (1). Diagnostic
investigation included CBC, serum chemistry, urinalysis, total serum bile acids, fasting plasma ammonia, as well as abdominal radiography and ultrasonography. Cardiovascular interventional diagnostics were used to confirm the diagnosis of EHPSS and attempt correction. All dogs that presented for suspicion of EHPSS and had informed owner consent for this technique were included in the study.

**Cranial Mesenteric Arterial Portography (CMAP)**

As determined by the anesthesiologist on duty, all dogs had similar anesthetic protocols consisting of an opioid given before induction, induction of anesthesia with propofol, and maintained with isoflurane in oxygen. Dogs were placed in lateral recumbency and the femoral artery was exposed with a vascular cut-down followed by the insertion of a 4 Fr vascular sheath via a modified Seldinger technique. An angiographic catheter and guide wire were directly inserted into the femoral artery and guide wire were advanced to the level of the diaphragm with fluoroscopic guidance. In animals where the femoral artery was too small for a vascular sheath an angiographic catheter and guide wire were directly inserted into the femoral artery. The catheter was withdrawn caudally where 2 ventral deviations (drops) of the tip were seen. The 1st drop indicated the origin of the celiac artery while the 2nd drop indicated the origin of the cranial mesenteric artery. When the 2nd drop was noted, the catheter was advanced cranially and assumed the characteristic shape of the cranial mesenteric artery. By means of a syringe, 1–3 mL of a nonionic contrast agent was injected to verify the tip of the catheter was in the central channel of the artery and not a smaller side branch. CMAP was then performed by injecting approximately 2.2 mL/kg of contrast agent with 150 mmHg pressure over a period of 3–4 seconds. All dogs had CMAP performed in lateral recumbency with ventrodorsal CMAP performed if necessary to adequately define the shunt.

**Initial Experience with Experimental Flow Restrictor (FR)**

Our initial experience with EHPSS correction was with an experimental FR device similar to the AVP (Fig 1). The FR is cylindrical in shape and composed of a nitinol wire mesh with 2 holes on each end, which obstructs most of the flow through the blood vessel of interest allowing persistent flow through these holes.

The 1st dog was a 1.4-year-old, 1.5-kg MN Yorkshire Terrier that had a single EHPSS. An FR was chosen that was approximately 150% of the diameter of the EHPSS. The CMAP was repeated, which demonstrated flow through the EHPSS only through the holes of the FR. The heart rate and blood pressure were stable over a period of 10 minutes and the FR was fully deployed by releasing it from the delivery cable. The dog recovered uneventfully and was discharged the next day with instructions to continue medical treatment for HE. Abdominal ultrasound was performed 1 month after the procedure, which identified the FR and revealed persistent EHPSS flow through the FR. The dog was discharged with a plan to continue medical treatment for HE and return in 1 month for final correction of the EHPSS. Three weeks later the dog was accidentally pushed down a steep flight of steps and died from a gastric rupture and subsequent septic peritonitis. The body was available for necropsy, which revealed endothelialization of the FR except for the holes at each end.

The 2nd dog was a 1.9-year-old, 3.2-kg MN Bichon Frise that had a single EHPSS located between the diaphragm and liver. An FR was chosen that was approximately 200% the diameter of the EHPSS but the ability of the EHPSS to dilate with the FR was compromised. This resulted in the FR having an exaggerated “dog bone” appearance described for adequate AVP deployment. The CMAP was repeated, which revealed no flow through the EHPSS and substantial flow through the portal vein with intense opacification of the hepatic parenchyma. The dog did not develop systemic arterial hypotension or reflex tachycardia, signs consistent with severe portal hypertension; so the FR was released from the delivery cable. Our conclusion was that the holes at each end of the FR were occluded because of the restricted expansion of the FR or fibrin deposition. The dog recovered uneventfully and was monitored in ICU where clinical signs consistent with severe portal hypertension did not develop. The dog did very well for approximately 1 month with resolution of presenting clinical signs and normal fasting and postprandial bile acids. However, 2 months later there was a return of clinical signs and increases in both fasting and postprandial bile acids. The dog returned to the PUVTH for CMAP, which revealed flow through the FR. We hypothesized that inherent fibrinolysis allowed the holes to open up on the FR resulting in the return of flow through the EHPSS.

Based on our experience with the FR, we concluded that (1) when appropriately sized, the FR would have persistent flow that will require a second procedure and device for complete EHPSS occlusion; and (2) some dogs may be able to tolerate acute correction of an EHPSS, so a device such as the AVP may be a viable option for intravascular correction of EHPSS.

**Acute EHPSS Correction with the AVP**

In a similar fashion to the FR, the dogs were anesthetized and placed in lateral recumbency, a cut-down was performed on the femoral artery, and a CMAP was used to identify the EHPSS. As determined by the angle of insertion of the EHPSS into the caudal vena cava (CdVC), a jugular venous (caudal to cranial insertion angle or portoazygous shunt) or ipsilateral femoral venous (cranial to caudal insertion angle) cut-down was performed. Depending upon the size of AVP used, either a 5 Fr or 7 Fr long flexible vascular sheath was inserted into the vein and advanced to the approximate level of the insertion of the EHPSS into the CdVC or azygous vein. A 5 Fr angiographic catheter with a sharp curve on the distal end was inserted through the venous vascular sheath and advanced so that approximately 1–3 cm of the distal tip was extending beyond the distal end of the vascular sheath. Using a still frame from the CMAP for reference, the distal tip of the angiographic catheter was maneuvered to see if the insertion of the AVP could be engaged. The location of the tip of the catheter was confirmed by the injection of 1–3 mL of contrast agent. If necessary, a CMAP was repeated to identify the insertion site. A flexible guide wire was advanced through the catheter to assist further insertion of the catheter into the EHPSS. The vascular sheath was advanced over the catheter into the EHPSS or azygous vein and the catheter and guide wire were removed.

Fig 1. Picture of a flow restrictor (left) and Amplatz vector vascular plug (right). The flow restrictor is similar in shape but contains polyester fabric and has 2 central holes (⁎) that allow blood flow after deployment within the vascular lumen.
A 5 Fr or 7 Fr balloon wedge catheter was inserted into the vascular sheath and advanced past the distal tip into the EHPSS or azygous vein. The balloon was inflated to completely occlude the EHPSS or azygous vein and this was maintained for at least 10 minutes. If the heart rate increased or systemic arterial blood pressure (ABP) dropped with inflation, this was considered evidence of severe acute portal hypertension, suggesting the dog could not tolerate acute complete correction. A CMAP was repeated to verify complete occlusion and determine the portal venous anatomy and degree of portal flow through the hepatic parenchyma. If no evidence of severe portal hypertension occurred and establishment of portal hepatic flow was confirmed, then it was concluded the dog could tolerate acute correction of the EHPSS. The balloon was deflated and the catheter removed.

An AVP was chosen that was approximately 130–200% the diameter of the EHPSS from the CMAP. The AVP was inserted into the vascular sheath and advanced until it was deployed from the distal tip of the vascular sheath (Fig 2). The AVP was left in place for approximately 10–20 minutes to observe for any changes in heart rate or ABP. The CMAP was repeated again to confirm complete occlusion of the EHPSS and establishment of portal hepatic flow (Fig 2). After the confirmatory CMAP, the AVP was released from the threaded delivery cable. The femoral artery and vein were ligated in standard fashion while the jugular vein was repaired with 5-0 polypropylene in a simple continuous pattern. The vascular cutdown sites were closed by routine techniques.

Dogs were recovered from anesthesia and monitored in the ICU for 12–24 hours after the procedure. Fluids were administered at 60–100 mL/kg/d IV for approximately 2 hours after anesthetic recovery to facilitate contrast excretion. The amount and time of fluid administration were estimated by the fluid load the dog received during the procedure as well as residual contrast within the kidneys at the end of the procedure. This estimation is based on empirical clinical experience at our institution. Other investigators or institutions might have different clinical experience or subjective guidelines. The dogs were observed for the development of severe acute portal hypertension evidenced by vomiting, bloody diarrhea, delayed anesthetic recovery, or collapse or complications from EHPSS correction including bleeding from vascular insertion sites, or seizures. Medical treatment for HE was continued during this time.

Results

The breeds of dog were Miniature Schnauzer (2), Maltese (2), Pembroke Welsh Corgi (1), Pug (1), and Yorkshire Terrier (1) with 2 males (1 MN, 1 MI) and 5 females (2 FI, 3 FS). The median (range) age and weight was 1.20 years (0.2–2.6) and 4.4 kg (2.25–9.1), respectively.

Abnormalities included increased ALT (4/7), and ALP (5/7) with decreases in BUN (4/7), albumin (2/7), glucose (1/7), total protein (3/7), hematocrit (2/7), and MCV (1/7). Three of the 7 dogs were isosthenuric with crystalluria noted in 1/7 dogs. Fasting ammonia concentrations were measured in all dogs, with increases noted in 5/7 dogs. Fasting bile acids were increased in 6/7 while postprandial bile acids were measured in 4 dogs with 4/4 having values above normal.

Abdominal radiography identified microhepatia in 7/7 dogs. Abdominal ultrasonography definitively diagnosed an EHPSS in 2/7 dogs although in 3 additional dogs an abnormal vessel was noted but could not be confirmed to be an EHPSS. Bilateral nephroliths were noted in 1/7 dogs and echogenic debris within the urinary bladder was noted in 1/7 dogs.

An EHPSS was definitively diagnosed on CMAP in all dogs with 5/7 having portocaval and 2/7 with portazygous connections. Of the 5 dogs with a portocaval EHPSS, we originally diagnosed 3/5 with 2 vessels that entered into the CdVC through a confluence vessel of variable length (Fig 3). In retrospect, this confluence vessel could have been the distal continuation of the primary EHPSS where the secondary EHPSS inserted just proximal to the primary EHPSS insertion into the CdVC.

Seven AVP were deployed in 6 dogs with complete occlusion of the EHPSS achieved in 5/6 dogs. The 7th dog experienced an acute increase in heart rate and decrease in ABP with balloon occlusion, suggesting development of severe acute portal hypertension and intolerance to acute EHPSS correction. This response was repeatable with subsequent balloon occlusions and a CMAP during balloon occlusion failed to demonstrate any hepatic portal flow. It was determined this dog could not tolerate acute correction of the EHPSS so the procedure was aborted. The additional dog that could not be completely corrected had the 2-vessel pattern mentioned previously. An AVP completely occluded the primary vessel while...
the other could not be entered adequately to deploy a second AVP. Of the remaining 2 dogs with this multiple vessel pattern, 1 dog was corrected with 1 AVP deployed immediately proximal to the CdVC while the other dog was corrected with 2 AVP, 1 in each vessel proximal to the shared vessel insertion into the CdVC. The mean (±STD) for total procedural time, fluoroscopy time, and contrast dose for the group was 177.9 minutes (68.5), 20.6 minutes (9.8), and 10.5 mL/kg (5.2), respectively.

There were no complications noted in any of the dogs except for mild bruising around the site of the femoral arterial cut-down seen in 1 dog. All dogs were discharged from the hospital within 24–48 hours after the procedure and instructed to continue HE treatment.

Of the 5 dogs that had successful correction of their EHPSS, 4/5 had normal fasting and postprandial bile acids within 1 month after the procedure. The remaining dog had bile acids repeated 2 months after the procedure where fasting concentrations were normal (1.0 µmol/L; normal reference <13) with a mild increase in postprandial concentrations (51.8 µmol/L; normal reference <25). This pattern has remained consistent up to 13 months after the procedure although fasting ammonia concentrations have been normal. Medical treatment for HE was discontinued within 1 month for 4/5 dogs and for 5/5 dogs within 6 months. All dogs had resolution of clinical signs before the procedure although 1 dog developed blindness immediately prior (<24 hours) to EHPSS correction and this has remained persistent.

Discussion

Catheterization of the EHPSS and deployment of the AVP were relatively easy although there was a learning curve. Given the small number of dogs and anatomic diversity of the EHPSS, we cannot say that any of the cases were exactly the same or that the procedure became routine. The AVP has been used in arterial applications within the veterinary literature but this is the 1st report of its use in the venous circulation. The AVP has been used successfully and safely in the venous circulation in humans, including isolated reports of correction of portosystemic anomalies. It is important to point out that 3/5 dogs had the 2 vessel pattern mentioned previously. In 2/3 dogs, only 1 vessel was identified on the initial CMAP where the 2nd vessel was identified only after the primary vessel was obstructed by the balloon wedge catheter. With this pattern, both vessels must be occluded for successful correction. This could involve a single AVP immediately proximal to the CdVC insertion or 2 AVP with one placed in each of the vessels. We used both approaches in this study and found them to be equally effective. The dog that could not have both corrected by the AVP presented earlier in the study when we had less clinical experience with the technique. We feel with our additional experience this outcome would be less likely. It is noteworthy that the majority of the dogs in this study could be acutely corrected without developing severe portal hypertension. To the authors’ knowledge, this is the highest reported percentage of dogs tolerating acute complete shunt occlusion. Most importantly, all of our dogs were discharged after short hospital stays and improved at home with discontinuation of medical treatment shortly after correction.

The development of acute or subacute portal hypertension is considered the most severe complication and limitation with EHPSS correction. However, there are no objectively evaluated methods for determining what degree of portal hypertension is severe or correlation to correction outcome or survival. Surgical attenuation of EHPSS has been the treatment of choice with multiple variables used to identify portal hypertension. The most common variables used are visual changes to the abdominal viscera, mesenteric venous pressure (MVP), central venous pressure (CVP), and ABP. Using these parameters as guidelines, the literature reports that 17–66% of dogs with EHPSS can undergo acute complete attenuation. Because of the concern over development of severe portal hypertension with acute complete surgical ligation, gradual shunt attenuation with devices that can be placed during 1 surgical episode have become commonplace.
Visual changes to the abdominal viscera include cyanosis, pallor, congestion of mesenteric veins, pancreatic edema, increased mesenteric arterial pulsatility, and hypermotility of the intestines. These changes are subjective and may differ between surgeons. Additionally, there is no objective grading scale that has been correlated with actual development of portal hypertension or survival. We were precluded from visualizing the abdominal viscera so we cannot comment on the dogs in our study. However, given the dynamic nature of the CMAP, we are able to visualize the mesenteric arteries and veins for distension, tortuosity, and rapidity of flow through the portal system, which can suggest increased pressures and reduced portal flow.

Portal pressure is usually estimated by MVP. Personal observations and clinical experience has resulted in recommendations where a change in MVP of >8 mmHg (10 cm H2O) or maximal MVP of >15 mmHg (20 cm H2O) suggests excessive portal hypertension. However, there are many technical issues with MVP measurement that can make it unreliable and poorly repeatable. There are many technical issues with MVP measurement that can make it unreliable and poorly repeatable. There are no objective studies that correlate changes in MVP to surgical outcome, while 1 study could not correlate the measured MVP before or after ligation with long-term outcome. Finally, there are no reports that confirm when the suggested changes to MVP are exceeded, severe portal hypertension and poor clinical outcome occur. We could have recorded the shunt wedge pressure, which would estimate portal pressure. We attempted this in some dogs but, similar to MVP measurement, they were found to be unreliable and not repeatable. The primary reasons appeared to be catheter related and included collapse of the internal lumen of the catheter or obstruction of the distal end of the catheter with full balloon inflation.

The use of CVP and ABP as parameters for detection of portal hypertension have been used in previous studies. If the portal system is unable to accommodate the increase in blood flow, there will be pooling of blood within the abdominal viscera and reduction in cardiac preload and output; this will be manifested as a reduction in both the CVP and ABP, respectively with a reflex tachycardia. It has been suggested that decreases of >1 mmHg in CVP or >5–10 mmHg in ABP suggest the development of portal hypertension. An increase in heart rate >10/minute was also considered suggestive of portal hypertension. However, there are limitations to this technique for determining portal hypertension as well so individual investigators may decide to use a given technique based on their own clinical experience.

We were able to completely occlude the EHPSS with a balloon wedge catheter in 6/7 dogs. Of those 6 dogs, 5/6 demonstrated no change in ABP or heart rate over at least a 10-minute occlusion period and were able to tolerate complete occlusion with the AVP. One dog rapidly developed a reduction in ABP and concurrent increase in heart rate. When the balloon was deflated, an equally rapid reduction in heart rate and increase in ABP was noted. This pattern was repeatable with multiple inflations.

We have routinely performed CMAP to confirm the diagnosis of anomalous portosystemic connections over the past 9 years at our institution. We find the procedure a quick, easy, and minimally invasive diagnostic test that not only provides a definitive diagnosis for a portosystemic anomaly, but also provides valuable additional information with regard to anatomy (portocaval versus portovenous, congenital, or multiple acquired), semi-quantitative assessment of portal vein flow, and subjective assessment of portal pressures by visualizing the mesenteric veins with regard to tortuosities and rapidity of filling. CMAP has been suggested to be the angiographic technique of choice to diagnose portosystemic vascular anomalies previously within the literature; however, newer techniques have been described over the past decade so other investigators may prefer a different technique based on their own clinical experience. Using CMAP, we were able to further assess the portal circulation by visualizing portal structures and hepatic portal perfusion. In the dog that was intolerant to balloon occlusion, the CMAP failed to demonstrate any portal structures suggesting portal vein atresia and giving supportive evidence that the portal system in this dog could not tolerate acute correction of the EHPSS.

Some degree of portal circulation was evident on CMAP before occlusion in 3/7 of our dogs, which may suggest our high frequency of dogs that could tolerate complete occlusion. Previous studies have demonstrated that dogs with a well developed portal circulation on portography with temporary occlusion were more likely to tolerate complete correction. Swalec and Smeak reported that 39% of dogs with poor portal flow on temporary occlusion experienced operative complications while this was absent in all dogs with good portal flow. While the number of dogs in this study is severely limited and a broad conclusion based on this study would be inappropriate, we felt that the combination of CMAP with balloon occlusion of the EHPSS was able to identify those dogs that could tolerate acute correction of the EHPSS.

There are some notable limitations of this study, including the very small number of dogs. However, while the study size is too small to make any broad-based conclusions, the dogs appeared to be representative of the general EHPSS population at Purdue University with regards to breed, age, weight, presenting clinical signs, and degree of hepatic insufficiency. It should also be noted that this technique requires the availability of special equipment including fluoroscopy. Lastly, this technique does require experience with vascular interventions, but while specialized, we do not believe this is more complicated or difficult than the expertise required of a surgeon for surgical correction.

We conclude that acute correction of EHPSS in dogs utilizing the AVP is feasible and a possible viable alternative to surgical correction. There was 1 dog that could not be completely corrected by this technique while this would be an uncommon situation with traditional surgical techniques. However, we relate this case to experience and feel as though this would be less likely once greater clinical experience with this technique is obtained. Additionally, the use of CMAP with
temporary occlusion of the EHPSS may be useful in identifying dogs that can tolerate acute correction. These dogs could then undergo permanent correction with an AVP or complete surgical ligation.

Footnotes

a Amplatzer Vascular Plug, Infini Medical, Malibu, CA
b RCF-4.0-21-5-J, Cook Medical, Bloomington, IN
c HNB4.1-38-10-P-NS-JR3, Cook Medical
d TSCF-35-145-1.5, Cook Medical
e Exposcope 7000, Ziehm Imaging Inc, Orlando, FL
f C3F100C1, BALT Extrusions, Montmorency, France
g TSF-21-145, Cook Medical
h Ultravist 300, Bayer Healthcare Pharmaceuticals, Wayne, NJ
i Mark V ProVis, MEDRAD Inc, Warrendale, PA
j Experimental flow restrictor, AGA Medical Corp, Plymouth, MN
k KCFW-5.0-38-38-55-RAABE, Cook Medical
I KCFW-7.0-38-38-55-RAABE, Cook Medical
m HNB5.0-38-100-P-NS-JR3, Cook Medical
n TSFB-35-145-BH, Cook Medical
o AI-07124, Teleflex Inc, Reading, PA
p AI-07127, Teleflex Inc

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