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Use of intraoperative transsplenic injection of agitated saline to confirm temporary full attenuation of congenital extrahepatic portosystemic shunts in dogs

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Abstract

Objective: To describe the use of intraoperative transsplenic injection of agitated saline (TIAS) and confirm temporarily full attenuation of extrahepatic portosystemic shunt (EHPSS) in dogs.

Study design: Retrospective case series.

Animals: A total of 40 dogs.

Methods: Medical records of dogs that underwent surgical attenuation of EHPSS between January 2014 and May 2021 were reviewed. A ventral midline celiotomy was performed, the EHPSS identified and dissected, and temporal occlusion performed using Rummel tourniquets or silicone vascular loops. A wide range microconvex transducer was used to visualize the right atrium via a subxiphoid acoustic window. Agitated saline was injected into the splenic parenchyma while the right atrium was ultrasonographically monitored before and after temporary occlusion of the EHPSS. Case details, intra- and postoperative findings, and long-term outcome were recorded.

Results: The agitated saline was immediately identified within the right atrium after injection into the splenic parenchyma before temporary occlusion of the EHPSS in all cases. After temporary occlusion, the agitated saline was not observed within the right heart, except in two dogs in which a second vessel bypassing the liver circulation was identified. No intra- or postoperative complications were recorded. Long-term clinical outcome was considered good to excellent in all cases.

Conclusion: Intraoperative TIAS confirmed temporary full attenuation of EHPSS.

Clinical significance: Intraoperative TIAS is an easy, safe and reproducible technique to assess intraoperative full occlusion of EHPSS.

Abbreviations: CTA, computed tomographic angiography; EHPSS, extrahepatic portosystemic shunt; IOMP, intraoperative mesenteric portovenography; IV, intravenous; SD, standard deviation; SP, splenoportography; TIAS, transsplenic injection of agitated saline; US, ultrasonography.

1 | INTRODUCTION

Congenital extrahepatic portosystemic shunts (EHPSS) are venous abnormalities that connect the portal vein, or its tributaries, with the systemic venous circulation. Several morphologies of EHPSS in dogs and cats have been described.[1,2]

The diagnosis of EHPSS is usually achieved by a combination of signalment, clinical history, physical findings, blood test and imaging techniques.[1,2] Ultrasonography (US),[3,4] positive contrast portovenography,[5,6] scintigraphy[7] or computed tomographic angiography (CTA)[8–10] have been described as diagnostic imaging tests for EHPSS.

CTA is considered the gold standard for evaluation of the portal venous system in humans.[11] CTA is a useful diagnostic technique to describe EHPSS configuration and detail all its branches.[11,12] It has been proposed as the ideal diagnostic technique when the shunting vessel is not identified using US[12] or during exploratory laparotomy.[13,14]

Portovenograpy techniques, such as intraoperative mesenteric portovenography (IOMP)[5,6,14,15] or splenoportography (SP)[16] have also been described for the diagnosis of the EHPSS.

IOMP is generally performed before and after temporary occlusion of the suspected EHPSS and requires the use of a C-arm fluoroscope to acquire intraoperative images. During IOMP, the contrast agent is injected in a tributary portal vessel to enhance extrahepatic vascularization to identify the EHPSS.[5,6,14,15]

An alternative to IOMP is SP. It is an intraoperative diagnostic technique in which contrast agent is injected into the splenic parenchyma to visualize the portal vein and its main tributaries.[16] Although SP may offer some advantages over other diagnostic modalities, it provides more intense enhancement of the splenic and main portal vein, and more inconsistent opacification of the hepatic parenchyma and portal branches, particularly those caudal to the splenic vein, such as the mesenteric vessels. Because of these limitations, SP may limit the identification of some EHPSS, as normal vascular structures used as landmarks may be missed.[16]

Although IOMP and SP are the only intraoperative imaging techniques that enable the visualization of the extrahepatic vascular anatomy and specific EHPSS location, they are not routinely used unless the location of the EHPSS is unknown or confirmation is required, or preoperative diagnostic imaging techniques were not conclusive.[6,14–16]

An alternative nondiagnostic imaging technique is the evaluation of changes in the portal pressure. It is an intraoperative technique that may be used when the EHPSS location is unclear, as a rapid increased in the portal pressure is normally observed when the EHPSS is occluded.[17]

Transsplenic injection of agitated saline (TIAS) has been previously reported in combination with cardiac US to identify macroscopic EHPSS.[18] TIAS implies the injection of several boluses of agitated saline solution percutaneously into the splenic parenchyma. Agitated saline is observed into the right atrium if a portosystemic shunt is present.[18] On the contrary, in normal dogs, the agitated saline cannot be seen in the right atrium because it gets trapped within the liver parenchyma.[18,19]

We proposed the intraoperative use of TIAS as a method to assess temporary full attenuation of EHPSS in dogs. We hypothesized that TIAS is a feasible, easy and an alternative intraoperative technique to IOMP and SP in dogs.

2 | MATERIALS AND METHODS

2.1 | Inclusion criteria

Dogs diagnosed with congenital EHPSS in our institution that were surgically managed between January 2014 and May 2021, were retrospectively reviewed. All dogs diagnosed with an EHPSS that underwent surgery in which an intraoperative splenic injection of agitated saline was used, were included in the study. Dogs were excluded if TIAS was not performed, or short-term follow-up was not available. Data recorded included signalment, EHPSS configuration, preoperative clinical signs, surgical time, intra- and postoperative complications. Short-term outcome, defined as time from surgery to the first 8-week postoperative recheck, and long-term outcome, defined as any follow-up performed until 6 months after surgery, were recorded.

2.2 | Preoperative evaluation and medical treatment

The diagnosis of EHPSS was made in all dogs based on clinical signs, pre- and postprandial bile acids concentrations, and was confirmed by abdominal Doppler US. EHPSS were classified into three categories: portocaval, portophrenic and porto-azygos. Dogs were medically managed for 4 weeks prior to surgery using lactulose (0.6 mL/kg orally every 8 h), metronidazole (7.5 mg/kg orally every 12 h), potassium bromide (20 mg/kg orally every 24 h) and a liver-specific diet.

2.3 | General anesthesia

All dogs were premedicated with methadone (0.3 mg/kg) and medetomidine (0.01 mg/kg), both administered by intramuscular injection. General anesthesia was induced with propofol (4 mg/kg) administered intravenously (IV) through a peripheral catheter and maintained with isoflurane vaporized in oxygen. Perioperative crystalloid fluid therapy (5–10 mL/kg/h) was used to maintain systemic blood pressure. Intravenous cefazoline (22 mg/kg) was administered immediately before surgery and thereafter every 90 min during the procedure. Carprofen (2 mg/kg) was administered IV preoperatively for additional analgesia.

2.4 | Surgical procedure

A ventral midline celiotomy was performed. The suspected EHPSS was visually identified. The EHPSS morphology was confirmed by visual inspection and compared with the information provided by the preoperative abdominal ultrasound (US). The EHPSS was dissected as close as possible to its draining into the systemic circulation, which means, at the level of the epiploic foramen for EHPSS draining into the prehepatic caudal vena cava, at the insertion into the left phrenic vein for EHPSS draining into this vessel, or at the level of the esophageal hiatus for EHPSS draining into the azygos vein. After dissecting the EHPSS, one or two strands of 2-0 USP silk sutures were placed around the vessel and a Rummel tourniquet applied using the suture material and an 18 gauge IV catheter. Alternatively, one or two strands of medical grade silicone vascular loop were used for the same purpose. The tourniquets were left loose.

A wide range microconvex transducer (10.2–4.2 MHz) was used to visualize the right atrium and right ventricle of the heart via a subxiphoid acoustic window (Figure 1). The transducer was covered with a sterile ultrasound probe cover and placed in contact with the abdominal surface of the diaphragm. To improve visualization, warm sterile 0.9% saline solution was poured between the transducer, liver, and diaphragm.

A 22 gauge hypodermic needle was attached with a flexible extension tube to a three-way stopcock with two 5 mL syringes: one with 5 mL 0.9% saline solution, and the other one empty with 0.5 mL of air. Both syringes were connected at right angles at the three-way stopcock.[19] With the transducer in place, the saline was agitated back and forth between the two syringes and the needle inserted in the parietal surface of the ventral extremity of the spleen (Figure 2). A 2 mL bolus of the solution was injected into the spleen and the presence of


FIGURE 1 Intraoperative image showing the position of the ultrasound (US) probe in contact with the diaphragm (subxiphoid acoustic window).


FIGURE 2 Intraoperative image showing the preparation of the agitated saline. Two 5 mL syringes were connected to a three-way stopcock. Then 5 mL of 0.9% saline solution were agitated back and forth between the two syringes, creating microbubbles.

the agitated saline into the cardiac chambers confirmed as small intense echo signals (microbubbles) within seconds (Figure 3). The Rummel tourniquets or vascular loops were fully tightened around the EHPSS and TIAS
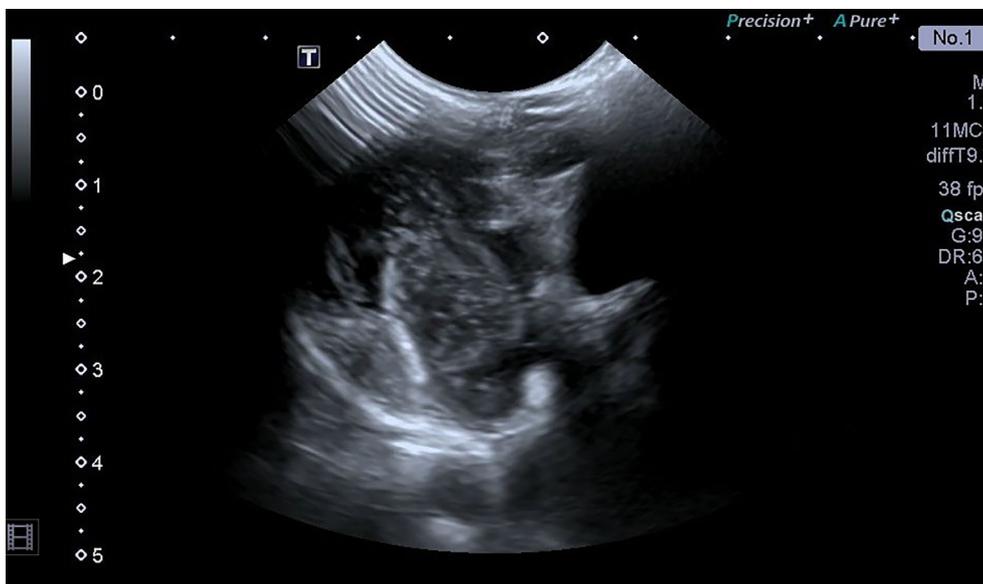
FIGURE 3 Ultrasound image of the microbubbles within the right atrium and ventricle in a dog before extrahepatic portosystemic shunt (EHPSS) temporary occlusion.
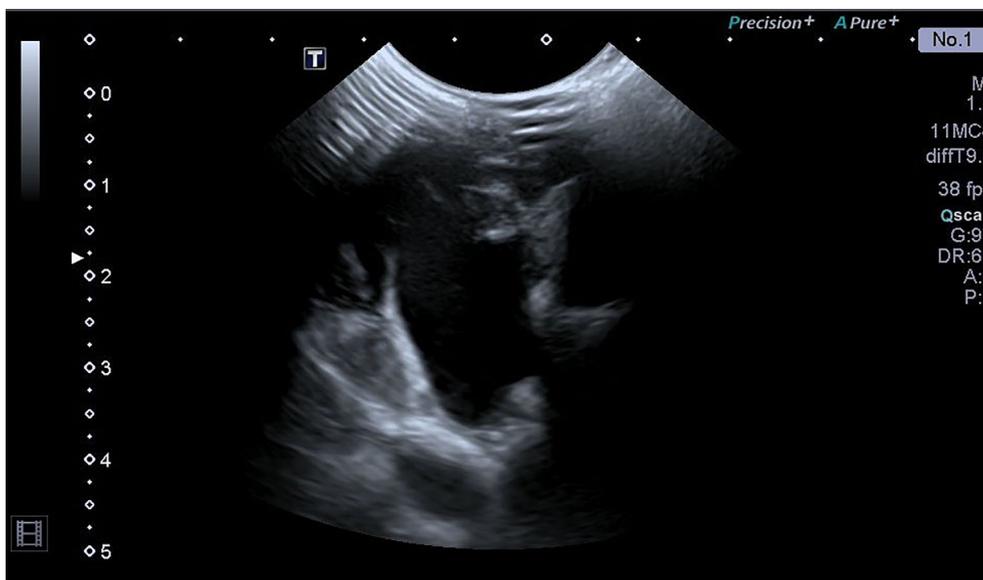
FIGURE 4 Ultrasound image of the right atrium and ventricle of the same dog after temporary extrahepatic portosystemic shunt (EHPSS) occlusion. No microbubbles are identified in the right cardiac chambers.

repeated. The absence of microbubbles into the cardiac chambers confirmed EHPSS location and complete occlusion (Figure 4). If macroscopic splenic bleeding was identified from the puncture site, it was managed by gentle digital pressure until the bleeding stopped. Macroscopic changes observed in the spleen were also recorded.

Once the EHPSS was unequivocally identified, an ameroid constrictor was placed around it and the tourniquets or vascular loops removed. The abdominal cavity was lavaged with sterile saline and the celiotomy routinely closed in 3 layers. No attempts were made to achieve an intraoperative full EHPSS closure.

Postoperative analgesia was provided for all dogs in the form of methadone 0.3 mg/kg IV every 4 h the first day, followed by oral transmucosal administration of buprenorphine 0.02 mg/kg every 6 h for 3 days. All dogs were discharged with instructions to continue the preoperative medical treatment for an additional 2 weeks and maintained the dietary management until the 8-week-recheck.

2.5 | Postoperative outcome evaluation

All dogs were rechecked 8 weeks postoperatively by their referring veterinarians. A blood sample was obtained to assess pre- and postprandial bile acids. When possible, a recheck examination and a follow-up abdominal US was performed in our hospital to evaluate the absence or persistent blood flow through the EHPSS.

Long-term clinical outcome was evaluated by owner telephone questionnaire at ≥6 months postoperatively.

Clinical outcome was classified as excellent, good, or poor, as defined by previous reports.[20–22] Briefly, an excellent outcome includes dogs with no clinical signs related to the EHPSS and no requirements for medical treatment or liver-specific diet. A good outcome, dogs with no clinical signs related to the EHPSS but requirements for dietary restrictions, antimicrobials, lactulose and/or anticonvulsants. Finally, a poor outcome includes dogs with persistent clinical signs that were likely associated with the EHPSS or dogs who died for reasons related to the EHPSS.

2.6 | Statistical analysis

Descriptive statistics were used for all variables. A Shapiro–Wilk test was done for all numeric variables and results are expressed as median and interquartile range (IQR), or mean and standard deviation (SD) depending on the results of the normality test.

3 | RESULTS

A total of 40 dogs fulfilled the inclusion criteria. No dogs were excluded within the study period. Clinical data are recorded in Table 1. Breeds represented were Yorkshire Terrier ($n = 21$), crossbreed ($n = 5$), Chihuahua ($n = 3$), Maltese ($n = 3$), and one each of the following: Shih-tzu, Pomeranian, Pug, Miniature Poodle, Miniature Pinscher, Miniature schnauzer, Golden Retriever, and Labradoodle. Median age was 24 months (IQR 11–45). There were 21 males and 19 females. Median bodyweight was 3.3 kg (IQR 2.0–5.0).

All dogs were referred with clinical signs consistent with a diagnosis of EHPSS, including neurological, gastrointestinal and urinary signs, or a combination of them. Preoperative bile acids concentrations were available for 33 dogs. Median preoperative preprandial bile acids concentration was 123 μmol/L (IQR 50–202). Median preoperative postprandial bile acids concentration was 207 μmol/L (IQR: 111–295).

Diagnosis was confirmed by abdominal US in all dogs. Regarding EHPSS morphology, there were 16 portocaval, 12 portophrenic and 10 porto-azygos shunts. Additionally, there was one dog with two different EHPSS types, one porto-azygos and one portophrenic shunt (dog 3), and another dog with a duplicated porto-azygos shunt (dog 23).

Mean surgical time was 70 ± 15 min. The TIAS confirmed the EHPSS and temporary full closure in all but two dogs. The first one was an 8-year-old Shih-tzu with a porto-azygos shunt in which two Rummel tourniquets

were placed as close as possible to the esophageal hiatus. The abdominal cavity was re-explored and a second anomalous vessel, arising from the left gastric vein and draining into the left phrenic vein was identified (classified as portophrenic shunt). Two additional Rummel tourniquets were placed around this second vessel and tightened prior to repeating the TIAS procedure, which confirmed full EHPSS closure. The second dog was a 2-year-old Yorkshire Terrier with a double loop EHPSS inserted into the azygos vein, with one loop coming from the lesser curvature of the stomach and another coming from the splenic vein (Figure 5). Both loops were temporarily closed and TIAS repeated, confirming EHPSS closure. In both dogs, two ameroid rings were placed, one on each abnormal vessel location (Figure 6).

No intraoperative complications or macroscopic splenic changes were observed, apart from very mild splenic bleeding at the TIAS puncture site in all dogs that was easily addressed by digital pressure and resolved in a few minutes. No postoperative complications occurred in any dog.

3.1 | Postoperative outcome evaluation

Postoperative bile acids concentrations were available for 33 dogs. Median postoperative pre- and postprandial bile acids concentrations were 5 μmol/L (IQR 2.1–19) and 25 μmol/L (IQR 16–40), respectively.

Postoperative 8-week abdominal US could only be performed in 15 dogs. Absence of persistent blood flow through the EHPSS was confirmed in all of them.

3.2 | Long-term follow-up

A total of 39 owners were reached for the long-term phone follow-up. One dog was lost for the long-term-follow-up. Mean follow-up time was 3 ± 1.5 years.

Outcome was classified as excellent in 29 dogs, and good in 10, of which all required long-term dietary management but no medical therapy. Three dogs died for reasons unrelated to the EHPSS. However, before death, outcome was recorded as excellent in these three cases.

4 | DISCUSSION

TIAS was successfully performed in all cases even in dogs presented with variations in EHPSS morphology. The technique was effective, easily performed, it did not cause intra- nor postoperative complications, and confirmed temporary full attenuation of the EHPSS. This technique

TABLE 1 Clinical data of dogs who underwent surgical attenuation of extrahepatic portosystemic shunts.

Case number	Breed	Age (months)	Body weight (kg)	Sex	EHPSS morphology	Size of ameroid constrictor (mm)	Preprandial preoperative bile acids (μmol/L)+	Postprandial preoperative bile acids (μmol/L)+	Preprandial postoperative bile acids (μmol/L)+	Postprandial postoperative bile acids (μmol/L)+	Long-term clinical outcome	Follow-up US findings
1	Yorkshire Terrier	48	2.0	m	Portocaval	3.5	266	287	32	54	Excellent	
2	Yorkshire Terrier	32	1.9	m	Portocaval	5	115	125	10	24	Excellent	
3	Shih-tzu	96	7.5	f	Porto-azygos and portophrenic (two different configurations)	3.5/5	245	307	190	250	Good	
4	Pug	24	7.0	f	Porto-azygos	7	196	289	4	28	Excellent	
5	Yorkshire Terrier	36	3.0	m	Portophrenic	5	1	46	1	48	Excellent	
6	Yorkshire Terrier	60	4.7	m	Portocaval	3.5	247	282	3	7.3	Excellent	
7	Crossbreed	4	4.0	f	Portophrenic	5	9.2	123	0.5	47	Good	
8	Yorkshire Terrier	12	3.0	m	Portocaval	3.5	29	150	8	17	-	
9	Yorkshire Terrier	9	3.0	m	Portocaval	3.5	123	143	10	32	Excellent	
10	Yorkshire Terrier	12	1.5	f	Portophrenic	3.5	6	35	5	15	Excellent	
11	Miniature Schnauzer	8	7.0	m	Portophrenic	5	176	464	1	31.8	Excellent	
12	Crossbreed	12	3.0	m	Porto-azygos	5	158	193	1.3	12.3	Excellent	
13	Chihuahua	24	2.0	m	Porto-azygos	3.5	83	139	20	43	Excellent	
14	Crossbreed	60	5.0	m	Portophrenic	5	26	149	1	73.9	Excellent	
15	Chihuahua	6	1.0	m	Portocaval	3.5	152	207	10	23	Excellent	Normal liver size No focal or diffused changes in liver parenchyma Absence of blood flow through the EHPSS

TABLE 1 (Continued)

| Case number	Breed	Age (months)	Body weight (kg)	Sex	EHPSS morphology	Size of ameroid constrictor (mm)	Preprandial preoperative bile acids (µmol/L)+	Postprandial preoperative bile acids (µmol/L)+	Preprandial postoperative bile acids (µmol/L)+	Postprandial postoperative bile acids (µmol/L)+	Long-term clinical outcome	Follow-up US findings
16	Yorkshire Terrier	72	5.0	f	Portophrenic	5	61	60.8	8	14	Excellent	Normal liver size No focal of diffused changes in liver parenchyma Absence of blood flow through the EHPSS; however, artifacts seen due to respiratory movements
17	Maltese	24	3.0	f	Porto-azygos	3.5	172	378	7	24	Good	Very mild reduced liver size Absence of blood flow through the EHPSS
18	Yorkshire Terrier	60	4.2	m	Portocaval	3.5	235	380	10	130	Good	Very mild reduced liver size Absence of blood flow through the EHPSS
19	Golden Retriever	36	20.0	m	Porto-azygos	7.5	142	208	11	22	Excellent	Normal liver size No focal of diffused changes in liver parenchyma Absence of blood flow through the EHPSS; however, artifacts seen due to respiratory movements
20	Yorkshire Terrier	24	5.0	m	Portocaval	5	40	78	3	15	Excellent	Normal liver size. No focal or diffused changes in liver parenchyma. Absence of blood flow through the EHPSS
21	Yorkshire Terrier	48	2.0	m	Portophrenic	5					Excellent	Normal liver size. Absence of blood flow through the EHPSS
22	Miniature Pinscher	10	2.0	f	Porto-azygos	3.5	85	253	8	13	Excellent	Normal liver size. Absence of blood flow through the EHPSS

(Continues)

TABLE 1 (Continued)

| Case number	Breed	Age (months)	Body weight (kg)	Sex	EHPSS morphology	Size of ameroid constrictor (mm)	Preprandial preoperative bile acids (μmol/L)+	Postprandial preoperative bile acids (μmol/L)+	Preprandial postoperative bile acids (μmol/L)+	Postprandial postoperative bile acids (μmol/L)+	Long-term clinical outcome	Follow-up US findings
23	Yorkshire Terrier	24	5.0	f	Duplicated porto-azygos	3.5/5	148	301	11	26	Excellent	Very mild reduced liver size. No focal or diffused changes in liver parenchyma. Absence of blood flow through the EHPSS
24	Yorkshire Terrier	60	4.0	f	Porto-azygos	5	621	588	15	36	Good	Very mild reduced liver size No focal or diffused changes in liver parenchyma Absence of blood flow through the EHPSS
25	Yorkshire Terrier	24	7.0	f	Porto-azygos	3.5	50	57	2	30	Good	Normal liver size Absence of blood flow through the EHPSS
26	Maltese	5	1.5	f	Portocaval	3.5	49	63	3	17	Excellent	Normal liver size. No focal or diffused changes in liver parenchyma. Absence of blood flow through the EHPSS
27	Crossbreed	12	10.0	f	Portocaval	5	233	252	4	8	Excellent	No information about liver size. No focal or diffused changes in liver parenchyma. Absence of blood flow through the EHPSS
28	Yorkshire Terrier	24	6.0	f	Porto-azygos	3.5	71	98	1	18	Excellent	Normal liver size. No focal or diffused changes in liver parenchyma. Absence of blood flow through the EHPSS

TABLE 1 (Continued)

Case number	Breed	Age (months)	Body weight (kg)	Sex	EHPSS morphology	Size of ameroid constrictor (mm)	Preprandial preoperative bile acids (μmol/L)+	Postprandial preoperative bile acids (μmol/L)+	Preprandial postoperative bile acids (μmol/L)+	Postprandial postoperative bile acids (μmol/L)+	Long-term clinical outcome	Follow-up US findings
29	Yorkshire Terrier	36	2.0	f	Portocaval	3.5	126	288	8	23	Excellent	Normal liver size. No focal or diffused changes in liver parenchyma. Absence of blood flow through the EHPSS
30	Yorkshire Terrier	5	3.0	f	Portocaval	5					Good	
31	Chihuahua	60	3.5	m	Portocaval	3.5					Good	
32	Maltese	11	5.0	m	Portocaval	5	123	178	10	25	Excellent	
33	Labradoodle	4	4.0	f	Portocaval	7	99	268	4	8	Excellent	
34	Yorkshire Terrier	36	3.0	m	Portophrenic	5					Excellent	
35	Yorkshire Terrier	10	1.5	m	Porto-azygos	5					Excellent	
36	Yorkshire Terrier	24	2.0	m	Portophrenic	3.5					Good	
37	Crossbreed	60	6.0	f	Portophrenic	5					Good	
38	Pomeranian	24	4.0	f	Portocaval	3.5	207	619	2.2	68	Excellent	
39	Yorkshire Terrier	12	2.0	m	Portophrenic	3.5	367	443	2.7	24.5	Excellent	
40	Miniature Poodle	12	2.5	f	Portophrenic.	3.5	45	59	1	29	Excellent	

Note: +Bile acids reference intervals -- > Preprandial: <14.9 μmol/L -- > Postprandial: <29.9 μmol/L.
Abbreviation: EHPSS, extrahepatic portosystemic shunt.
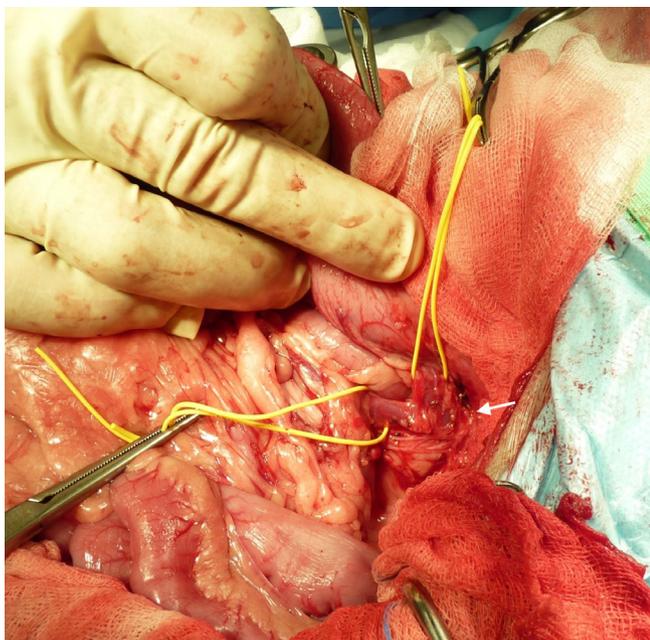
FIGURE 5 Intraoperative image of a duplicated porto-azygos shunt. Cranial is on the right of the image. Both branches have been isolated from the esophageal hiatus and lesser curvature of the stomach using vascular loops. The white arrow points at the position of the most ventral aspect of the diaphragm.
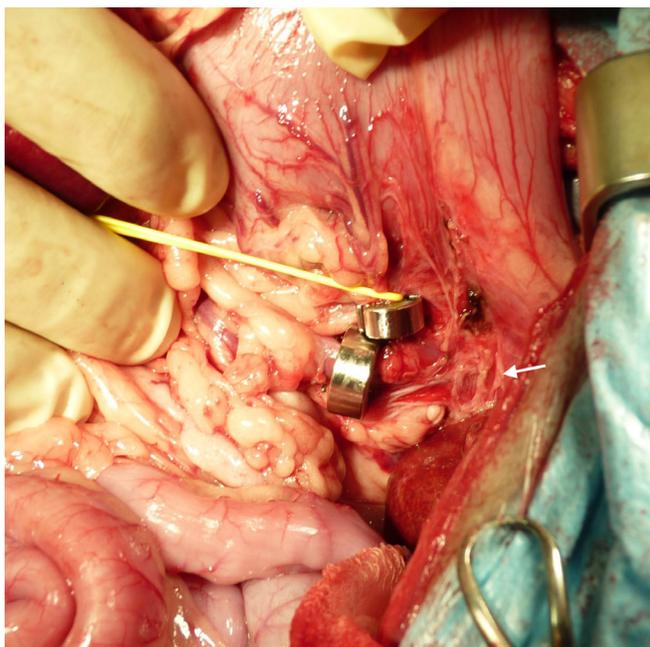
FIGURE 6 Intraoperative image of the previous patient after placing two ameroid rings around both branches of the shunt. Cranial is on the right of the image. The white arrow points at the position of the most ventral aspect of the diaphragm.

also allowed the detection of persistent shunting, such as the dog with a porto-azygos and a portophrenic shunt, and the dog with a duplicated porto-azygos shunt. These

EHPSS variations have been described in 2%–20% of cases,[23–29] and they have been identified as potential causes of persistent shunting when they are not individually addressed or the attenuating device is not properly placed.[23–25] Despite the advantages of TIAS to intraoperatively identify these EHPSS variations, our technique cannot predict if small tributaries might be missed, that can become larger in the postoperative period, causing persistent shunting and clinical signs, or causing the need for additional procedures.

TIAS, which had been previously described for the diagnosis of EHPSS,[18] was adapted in our cases for intraoperative use as a dynamic study, providing the surgeon valuable information before and after EHPSS temporary occlusion. Agitated saline combined with cardiac US has been described in human studies as early as 1968 to improve recognition of cardiac structures and anatomy by following the route of intracardiac blood flow.[30–32] Agitated saline combined with abdominal US has also been safely used in healthy dogs and dogs affected with EHPSS with no clinical complications described.[18,19] Similar to these studies, the intraoperative use of TIAS was safe in our dogs, with no complications observed intra nor postoperatively. Because of their small size and short stability, the microbubbles injected with TIAS cannot cross the pulmonary capillary bed and they are normally restricted to circulation within the right heart and pulmonary arteries.[33]

Changes in the portal pressure after temporary occlusion of EHPSS can also be intraoperatively used to correctly locate the shunt.[17] This technique implies catheterizing of a jejunal, the splenic or the portal vein, and attach the catheters to a transducer or water manometer. When EHPSS is temporally closed, a rapid increase in portal pressure is observed in most dogs. However, animals with high splanchnic compliance may experience minimal changes, thus reducing the sensitivity of the technique.[17] TIAS not only avoids the need for vein catheterization but also potential complications such as bleeding from the venipuncture sites. Although with our intraoperative technique minor bleeding was observed in the splenic parenchyma at the puncture sites, the bleeding was well controlled in a few minutes without further consequences.

The use of antimicrobials in combination with liver specific diet and lactulose has been widely used for preoperative and immediate postoperative management of EHPSS in dogs.[34] Although a recent study has questioned the benefit of using antibiotics for control of the clinical signs associated with EHPSS, all dogs were enrolled in our study prior to publication of the results of that publication, so the standard medical management of EHPSS was followed in our cases.[35]

4.1 | Limitations of the study

The use of abdominal US instead of CTA in the preoperative assessment of congenital EHPSS was one of the limitations of this study. CTA allows not only identification of the origin and insertion of the congenital EHPSS but also measurement of the EHPSS diameter,[8–11] which may help the surgeon to estimate the size of the attenuation device to use during surgery.[12] With the preoperative Doppler abdominal US, the EHPSS morphology and diameter of the abnormal vessel were properly identified in most of our cases. However, the origin of the EHPSS and its diameter were uncertain in a few dogs due to gas artifacts caused by the gastrointestinal tract and dog movements during the performance of the diagnostic test. The use of preoperative CTA could have addressed these issues and even help to preoperatively identify the two dogs with variations of the EHPSS morphology detected during surgery. However, it is important to understand the technique we described is not designed to substitute the use of CTA in the diagnosis of congenital EHPSS, but it is an alternative intraoperative method when IOMP, SP or measurements of portal pressures are not available, or it is elected not to use them. Additionally, the technique can be chosen in cases where CTA cannot be performed either for owner financial constraints, technical issues or inability to have access to this technology.

Another potential limitation of the TIAS technique was the likelihood of missing EHPSS located caudal to the main portal vein tributaries, such as colic or cranial rectal vein shunts.[36] As described by Ochoa et al., these caudal portosystemic shunts may not get involved in the microbubble pathway and could be potentially missed.[18] Although the incidence of these caudal portosystemic shunts is relatively low,[36] in cases where the preoperative abdominal US cannot identify the location of the EHPSS and a colic or cranial rectal portosystemic shunt is suspected, CTA is highly recommended.

Another limitation of our study was the use of US to assess EHPSS closure in the follow-up, which is not the most sensitive technique, particularly when development of multiple acquired portosystemic shunts occurs, as they could be easily missed. Postoperative CTA would have better evaluated if full EHPSS attenuation was achieved or if any dog developed multiple acquired shunts.[10] Despite the limitations of the postoperative abdominal US, no dogs required long-term medical therapy and only 10 required dietary management, so development of multiple acquired shunts or clinically significant persistent blood flow through the EHPSS was not suspected. Additionally, the use of US in these dogs avoided the need for sedation and decreased the costs.

Long-term clinical outcome and postoperative closure of an EHPSS cannot be predicted based exclusively on determination of blood variables, such as paired serum bile acids.[37] In our study, these values were only used in conjunction with the dog clinical status to orientate the clinician about the postoperative outcome.

Regarding the dog with a double loop or duplicated porto-azygos shunt, one could argue that a single attenuating device could have been placed closer to the intrathoracic insertion of the vessel into the azygos vein. In order to achieve that, access to the chest through a thoracotomy, thoracoscopy or transdiaphragmatic approach would have been required.[29] However, full long-term closure of these EHPSS may not be achieved even if a thoracic approach is used.[29] Considering that potential limitation and in order not to increase morbidity with an intrathoracic approach, it was elected to individually place two attenuating devices on each loop.

As this was a descriptive study, no comparisons can be made from our data and other intraoperative imaging techniques. Further studies comparing different intraoperative modalities would be required in order to evaluate if our technique provides similar sensitivity and specificity to the other previous reported intraoperative methods.

In conclusion, the intraoperative use of TIAS was an easy and quick method to assess temporary full attenuation of the EHPSS. It is also a feasible alternative to previous described intraoperative techniques such as IOMP. Although it is operator dependent, it only requires access to intraoperative US, so with the proper ultrasonographic skills, it may be accessible for most veterinary practices.

AUTHOR CONTRIBUTIONS

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest related to this report.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.