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NOTE

Surgery

Feasibility of complete surgical ligation on 72 dogs with singular extrahepatic congenital portosystemic shunt based on portal pressure and comparison of intraoperative mesenteric portovenography

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ABSTRACT. The relation between complete or partial ligation of extrahepatic portosystemic shunting and intraoperative mesenteric portovenography (IMP) was evaluated in 72 canines. Of the 72 dogs, 55 had complete ligation and 17 underwent partial ligation of abnormal vessels. IMP allowed evaluation of the number of intrahepatic portal branches and ratio of the diameter of cranial (CrPV) and caudal main portal vein (CaPV) at the shunt location. Nearly all cases in the complete ligation group and nearly half of the cases in the partial ligation group had three or more portal vein branches. CrPV/CaPV was 0.75 ± 0.24 in the complete ligation group and 0.29 ± 0.15 in the partial ligation group. CrPV/CaPV can be an effective new method for assessing IMP.

KEY WORDS: canine, portal pressure, portosystemic shunt, portovenography

Canine congenital portosystemic shunts (PSS) are characterized by an abnormal vessel between the portal venous system and systemic venous system, bypassing the typical intrahepatic circulation. Portal blood that normally flows through the liver instead enters directly into systemic circulation. Lack of blood flow through the liver leads to underdevelopment of the liver and often clinical symptoms of liver failure due to the lack of hepatic function. Although intrahepatic branches of the portal vein are usually formed, they are underdeveloped.

Diagnosis of PSS requires identification of abnormal vasculature by advanced imaging. In addition, imaging determines the anatomical location of the shunt vessel to most effectively proceed with surgical treatment, the most successful intervention for PSS. During surgery, the shunt vessel is identified, confirmed, and generally surgically ligated to block blood flow. In cases of underdeveloped intrahepatic portal veins, complete ligation of the shunt vessel results in portal venous hypertension, leading to multiple secondary acquired shunts and making it impossible to achieve complete resolution. Therefore, portal pressure should be measured throughout the process of shunt vessel ligation to determine if complete or partial ligation is appropriate. Complete ligation is acceptable if the difference between pre- and post-ligation portal pressure does not exceed 10 cmH_2O and the post-occlusion portal pressure is no greater than 20 cmH_2O [2].

Various imaging methods have been reported in the diagnosis and treatment of PSS [1, 3, 6–9]. Using intraoperative mesenteric portovenography (IMP), the shunt vessel and portal vein are visualized by injecting a contrast agent into the jejunal vein through a catheter inserted by celiotomy [8]. This method enables the identification and confirmation of a shunt vessel during surgery as well as the direct measurement of the portal pressure through the catheter in the jejunal vein. Several studies report the implication of IMP taken during temporary occlusion of the shunt vessel in determining intraoperative portal pressure and prognosis [4–7, 10]. We conducted a retrospective investigation of the associations between surgical shunt ligation criteria by portal pressure and IMP taken under temporary complete occlusion of the shunt vessel in dogs that had undergone surgery for previously diagnosed singular extrahepatic PSS. Our results introduce new evaluation methods and assessment criteria for IMP.

Subjects included 72 dogs with singular extrahepatic PSS that underwent an initial ligation procedure at Azabu University Veterinary Teaching Hospital between 2009 and 2015. The breed classifications of the 72 cases included in this study are as follows: 13 Yorkshire terriers (18.1%), 10 miniature Dachshunds, (13.9%), 10 toy poodles (13.9%), 7 Chihuahuas (9.7%), 7 Maltese (9.7%), 5 Papillons (6.9%), 5 miniature Schnauzers (6.9%), 3 Shih Tzus, (4.2%), 2 Pembroke Welsh corgis (2.8%), 2 mixed breeds (2.8%), 1 miniature pinscher (1.4%), 1 cocker spaniel (1.4%), 1 beagle (1.4%), 1 Pekingese (1.4%), 1 Pomeranian (1.4%), 1 Jack Russel terrier

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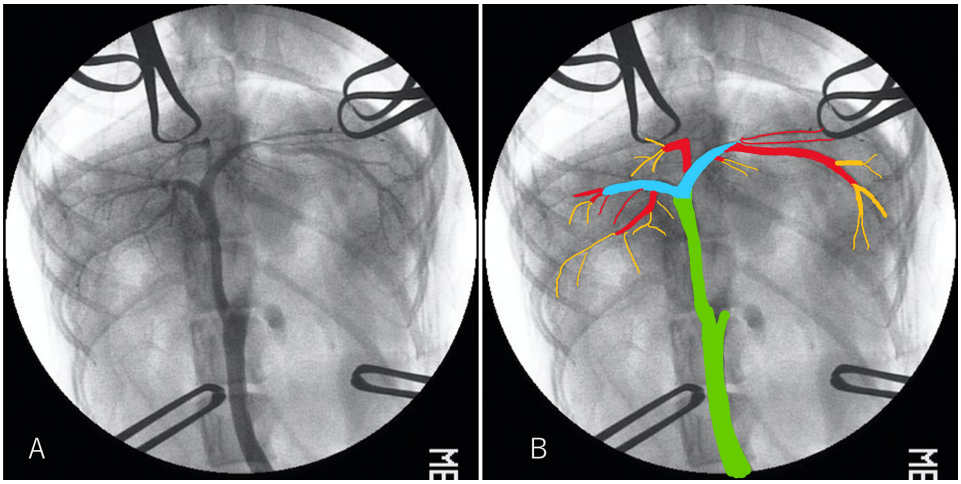

Fig. 1. Intraoperative mesenteric portovenogram taken after temporary complete occlusion of the shunt vessel. A: Original image B: Schematic image. The number of intrahepatic portal branches were classified into four types by the following method: vessels branching from the main trunk of the portal vein (green) that flow into the liver were classified as first-order branches (blue), vessels branching from first-order branches are second-order branches (red), and vessels branching from second-order branches are third-order branches (orange). Absent branching was visualized only green, first-order branches were denoted as green to blue, second-order branches were from green to red, and third-order branches were denoted as green to orange.

(1.4%), 1 Labrador retriever (1.4%), and 1 golden retriever (1.4%). There were 47 females (65.3%) and 25 males (34.7%), with a mean age of 2.56 ± 3.03 years and a mean weight of 4.18 ± 3.35 kg. None of the patients developed acquired shunts post-operatively.

In all cases, after 0.025 mg/kg atropine (ATROPIN SULFATE Injection, Tanabe, Osaka, Japan) was administered subcutaneously, 6–8 mg/kg propofol (PROPOFOL 1% Injection, Pfizer, Tokyo, Japan) was introduced intravenously as a general induction anesthetic. General anesthesia was maintained with isoflurane (ISOFLU, DS Pharma Animal Health, Osaka, Japan) inhalation. A median incision was made in the cranial abdomen, and a 20 to 24-G indwelling needle was inserted into the jejunal vein. Portal pressure was measured by connecting an invasive blood pressure monitor to the indwelling needle, and portal images were taken by IMP after a bolus injection of 370 mgI/m*l* iopamidol (OYPALOMIN Injection, Fuji Pharma, Tokyo, Japan) at a rate of 1.0 m*l*/kg through the same indwelling needle. The ventrodorsal fluoroscopic images were recorded. Baseline portal pressure was measured before occluding the shunt vessel. Next, portovenogram was taken to confirm the shunt vessel. After separating the shunt vessel, a 1–0 surgical silk suture was used for temporary complete occlusion of blood flow through the shunt vessel; subsequently, a second portovenogram was taken to measure post-occlusion portal pressure using the aforementioned method. Cases with a pre/post occlusion portal pressure difference ≤10 cmH_2O and post-occlusion portal pressure ≤20 cmH_2O underwent complete ligation of the shunt vessel using 1–0 silk suture. A partial ligation was performed in cases with portal pressure exceeding these values so as not to create risk of acquired shunts before closing the abdominal incision.

Portovenograms were taken when the shunt vessel was temporarily completely occluded, at the moment when the intra- and extrahepatic portal branches could be observed most clearly. The first method of assessment was to determine the number of intrahepatic portal branches after complete occlusion of the shunt vessel; they were characterized as follows: vessels branching from the hepatic portal vein flowing into the liver were considered first-order branches (1), those that further branched off of the first-order branches were defined as second-order branches (2), and those that branched from second-order branches were defined as the third-order branches (3) (Fig. 1), a comparison was made between the complete ligation group and the partial ligation group.

As a second method of assessment, transverse vessel diameters were measured at two points along the main trunk of the portal vein—at a point cranial to the shunt vessel (towards the liver, CrPV) and a point caudal to the shunt vessel (on the gastrointestinal tract side, CaPV), and the ratio was calculated by dividing CrPV by CaPV (CrPV/CaPV). The transverse diameter of the portal vein is affected by dog size or radiographic enlargement; therefore, the ratio of the diameters allowed more accurate comparison among the complete and partial ligation groups (Fig. 2).

Of the 72 cases, 55 (76.4%) were in the complete ligation group (i.e., the portal pressure was within standard values even after completely occluding the shunt vessel) and 17 (23.6%) were in the partial ligation group (i.e., the portal pressure exceeded standard values). Shunt vessel locations in the complete ligation group were classified as splenic vein to caudal vena cava (SC shunt) 16/55 (29.1%), left gastric vein to phrenic vein to caudal vena cava (LgPC shunt) 19/55 (34.5%), left gastric vein to caudal vena cava (LgC shunt) 1/55 (1.8%), right gastric vein to caudal vena cava (RgC shunt) 8/55 (14.5%) and left gastric vein to azygos vein (LgA shunt) 11/55 (20.0%). Partial ligation group shunts were identified as SC shunts 10/17 (55.8%), LgPC shunts 4/17 (23.5%), LgC shunts 1/17 (5.9%), RgC shunts 2/17 (11.8%) and LgA shunt 0/17 (0.0%). In the χ^2 test at a 5% significance level, there was a significantly higher occurrence of SC shunt.

In the 55 subjects in the complete ligation group, the number of intrahepatic portal branches was as follows: 0 (0 cases, 0%),

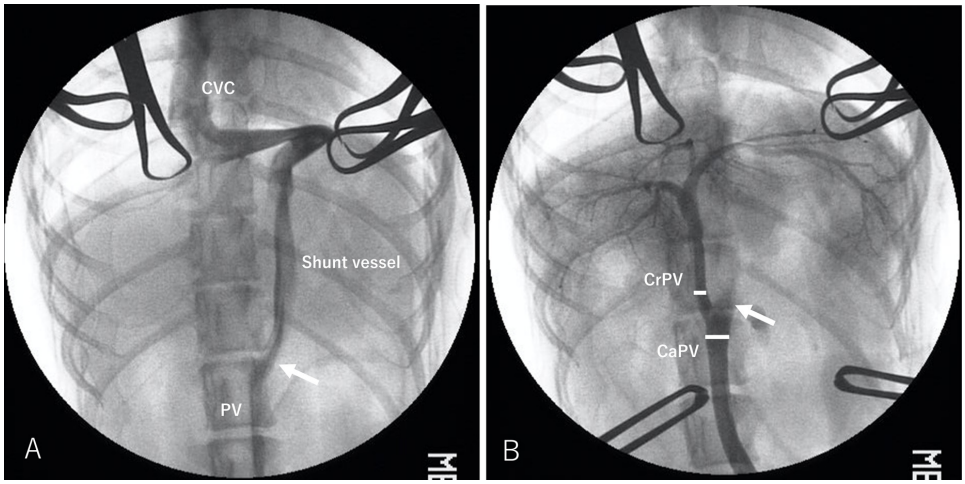

Fig. 2. A: Intraoperative mesenteric portovenogram taken before temporary complete occlusion of the shunt vessel. B: Intraoperative mesenteric portovenogram taken after temporary complete occlusion of the shunt vessel. The portal vein transverse diameter ratio was calculated by measuring the transverse diameter of the main trunk of the portal vein that flows into the liver at a point cranial (liver side) to the shunt vessel (CrPV) and at a point caudal (gastrointestinal tract side) to the shunt vessel (CaPV) and calculating the value of the CrPV/CaPV. The arrow shows a branch of shunt vessel from the main trunk of portal vein.

Table 1. CrPV/CaPV of the complete and partial ligation group

	Complete ligation group	Partial ligation group
Overall	0.75 ± 0.24	0.29 ± 0.15
SC shunt	0.69 ± 0.21	0.24 ± 0.15
LgPC shunt LgC shunt RgC shunt	0.77 ± 0.24	0.34 ± 0.09
LgA shunt	0.77 ± 0.27	

Mean ± Standard deviation.

1 (1 case, 1.8%), 2 (0 cases, 0%), and 3 or more (54 cases, 92.8%). In the 17 subjects in the partial ligation group, the number of intrahepatic portal branches was as follows: 0 (2 cases, 11.8%), 1 (4 cases, 23.5%), 2 (3 cases, 17.6%), and 3 or more (8 cases, 47.1%). Because these percentages did not show normal distributions, we performed Mann–Whitney's *U* test at a 5% significance level, which resulted in a significant difference in intrahepatic vasculature between the complete and partial ligation groups. Notably, nearly all subjects in the complete ligation group had three or more portal vein branches while approximately half of those in the partial ligation group had two or less branches. Therefore, a Fisher's exact probability test was performed at a 5% significance level to reveal a significant difference between trends in the occurrence of two or less and three or more portal vein branches in each ligation group.

CrPV/CaPV (mean ± SD) of overall cases was 0.75 ± 0.24 in the complete ligation group and 0.29 ± 0.15 in the partial ligation group. In SC shunts, which occurred significantly more often, the complete ligation group ratio was 0.69 ± 0.21 and the partial ligation group ratio was 0.24 ± 0.15. In LgPC, LgC and RgC shunts, with no significant difference in occurrence, the complete ligation group measured 0.77 ± 0.24 and the partial ligation group measured 0.34 ± 0.09. The LgA shunt which appeared only in the complete ligation group was 0.77 ± 0.27. Mann–Whitney *U* test was used to analyze the CrPV/CaPV of the two groups at a 5% level of significance; the ratios were significantly different (Table 1).

Identifying a shunt between portal and systemic circulation and understanding its anatomy are necessary for making a definitive diagnosis of and surgically correcting PSS. Radiographic portovenography, ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), and nuclear medicine scans are reported imaging methods used to verify the presence and anatomical position of the shunt [1, 3, 6–9]. IMP is a common type of portovenography that requires a contrast agent be injected through the jejunal vein to visualize the shunt vessels and portal vessels. This method has long been used as a diagnostic modality and does not require special equipment; however, a celiotomy under general anesthesia is necessary to obtain access for contrast agent injection, thereby making it a highly invasive and complex technique. In contrast, ultrasound examination requires no anesthesia or surgery, but has a shunt vessel detection rate of only 80% in even the best scenarios and does not allow any understanding of the course of the shunt vessel [8]. CT, MRI, and nuclear medicine scans can be performed under anesthesia alone but require special equipment and facilities. However, CT equipment is rapidly becoming more accessible in Japan, and with CT examination, systemic visualization of the vessels is possible using contrast agents injected into a peripheral vein. Given that the presence of the shunt

vessel and its anatomy can be checked in detail without a celiotomy, CT scan is more commonly used for the diagnosis of PSS, because the presence, position, and anatomy of the shunt vessel can be accurately confirmed preoperatively. Thus, in many facilities, intraoperative X-ray portovenography is not performed. Preoperative contrast-enhanced CT allows the visualization of various branches of veins that feed into the main trunk of the portal vein; therefore, this method is believed to be superior to IMP. However, after temporary complete occlusion of the shunt vessel, visualization of the cranial portal vein of the shunt vessel in CT images has been shown to be significantly inferior compared to IMP. Moreover, the degree of development of the intrahepatic portal vein seen on IMP with complete occlusion of the shunt has been shown to correlate with intraoperative portal pressure and postoperative prognosis in several clinical studies, suggesting the importance of a portovenogram when shunt vessel is occluded [4–7, 10].

In the present study, we classified subjects into those in which complete ligation was either possible or impossible based on portal pressure criteria to compare to the IMP after intraoperative temporary occlusion of the shunt vessel. All cases with less than two visualized intrahepatic branches underwent partial ligation, with only one exception. Cases treated by complete ligation had more than three branches with the exception of one; half of the cases that underwent partial ligation also had three or more branches. Thus, our results suggest that complete ligation was not possible in cases with two or fewer branches. Approximately half of the cases of partial ligation and all cases of complete ligation had three or more intrahepatic branches, suggesting there is a weak association between shunt vessel ligation criteria based on portal pressure and the numbers of intrahepatic portal branches. The comparison of the IMP taken before and after complete occlusion of a shunt vessel shows that the clarity of the intrahepatic portal vein increases significantly after occlusion. In particular, the portovenogram in dogs with completely occluded shunt vessels was reported to be superior, with higher visualization of intrahepatic portal vein, than that in a dog in which complete ligation could not be performed [5, 10]. However, the evaluation of the portovenograms was subjective and required an experienced examiner. Consistent with our study, a previous report in which intrahepatic branching was visualized by radiographic portography taken after temporary shunt vessel occlusion demonstrated a moderate correlation between the clarity of the intrahepatic portal branches and portal pressure [4]. Our results support these previous reports on association of portal pressure, the subjective clarity and the number of intrahepatic portal branches.

We also found a clear difference in CrPV/CaPV between the complete and partial ligation groups. CrPV/CaPV of SC shunt cases tended to be low, but in general, CrPV/CaPV was not influenced by the type of shunt vessel. Half of the partial ligation group is classified under the same grade as the complete ligation group when assessed based on the number of intrahepatic portal branches. CrPV/CaPV of the portal vein was calculated at (mean ± SD) 0.75 ± 0.24 in the complete ligation group and 0.29 ± 0.15 in the partial ligation group. Based on the mean and standard deviations, the subjects could be differentiated relatively clearly: with those having a CrPV/CaPV ≥0.5 being good candidates for complete ligation and those with a ratio ≤0.5 being candidates for only partial ligation. We theorize that complete ligation was possible in the dogs of ≥0.5 because of the slow flow rate of the shunted blood and the large capacity of the intrahepatic portal vein. Calculating the CrPV/CaPV ratio in this study proved to be a unique, simple, and more objective parameter for determining the best occlusion method. It has clearer assessment criteria for evaluating IMP than those used in existing reports and corresponds relatively well to the surgical ligation criteria of shunt vessels by portal pressure. Parry *et al*. explained that CT angiography cannot replace intraoperative mesenteric portovenography after temporary full ligation, as CT fails to provide information on intrahepatic portal vascularity. It is a practical and dynamic procedure, providing results that are instantaneously available at the time of surgery. In addition, intraoperative post-temporary, full-ligation, mesenteric portography confirmed that the single shunting vessel had both been recognized and ligated [7]. In conclusion, IMP is useful and CrPV/CaPV can be an effective new method of assessing IMP. However, our sample included only a small number of subjects that underwent partial ligation, and additional cases should be studied to attain more conclusive findings.

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