A Simple Calculation for Obtaining Shunt Fractions of Portosystemic Shunts

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ABSTRACT. Since the isotopes can not be utilized for veterinary patients in Japan, the authors developed a simple calculation formula of shunt fraction of portosystemic shunt based on the hepatic circulation model. The shunt fraction can be calculated utilizing on ly 2 portal pressure measurements of pre-shunt ligation and temporary or permanent shunt ligation. The calculated shunt fraction can obtained pre-ligation and post-ligation either temporally or permanent complete shunt ligation: complete ligation group of PSS (n=59) had 48.2 ± 10.7% of shunt fractions, whereas the partial ligation group (n=48) had 71.6 ± 10.7% of shunt fractions.

KEY WORDS: portal pressure, portosystemic shunt, shunt fraction.

Portosystemic shunt (PSS) creates shunt blood flow from portal vein to the systemic venous circulation. The shunt fractions were varied among cases and the shunt fractions would influence the method of surgical attenuation of the shunt vessels either complete, partial ligation and/or other modalities depending on the portal venous pressure at the time of temporally occlusion of shunt vessel. The liver receives approximately 25 to 30% of the cardiac output. The portal blood represents 80 percent and the hepatic arterial blood represents 20 percent of the total hepatic blood flow [1]. Thus, the amount of portal blood flow has a significant percentage of the hepatic blood flow. However, in cases of PSS, a significant amount of portal blood escapes into the systemic circulation. Previous studies of shunt fraction by radioactive isotopes demonstrated 76% (60–88%) [2] of the portal blood bypasses the hepatic circulation system which results in hepatic failure. Thus, the shunt fractions were obtained by use of isotopes, however, the uses of isotope for animal clinical cases were limited in Japan and shunt fractions have not been obtained. The shunt fractions would reflect the severity of pathological changes of hepatic mass as observed in cases of hepatic cirrhosis. If the shunt fraction is small, there would be minimum hepatic pathological change, however, if the shunt fraction is large, the hepatic pathological change would be significant. The shunt fraction is reflecting hepatic vascular resistance (HVR) and the portal blood flow are inversely related to HVR. We have developed mathematical model to calculate shunt fraction as follows.

The model of hepatic circulation has been designed by Mitzner with the use of an electrical current model [6]. A shunt circuit can be added to this model and the blood flow to the hepatic circulation and to the shunt can be simply estimated by the proportional differences of resistance for each circulation. By use of the simple hepatic circuit and the shunt model as shown in Fig.1, a shunt fraction can be obtained. Intrahepatic venous vascular resistance is negligible since the pressure gradients between the perisinusoidal space and the hepatic vein is small [4]. As confirmed by a previous study, the hepatic arterial occlusion had no influence on the portal pressure [8]. Considering these hemodynamic variables, a simple hepatic vascular circuit with PSS can be obtained under the following conditions: upstream portal blood flow is equal in the PSS and normal dogs; the auto regulatory response has not been considered; hepatic venous pressure and central venous pressure are equal to zero since there is no resistance between them [3, 4].

The shunt vascular resistance (Rs) and the intrahepatic portal vascular resistance (Rp) were calculated by utilizing the PSS circuit model (Fig. 2). Since the circuit of the shunt vessel and the portal vein run parallel in this model, the total vascular resistance (Rt) can be defined as the sum of the inverse number of each vascular resistance:

\[1/Rt = 1/Rp + 1/Rs.\]

Rs can be derived from the formula as

\[R_s = \frac{R_p \times (PVP/PVBF \times BW)}{(R_p - PVP/PVBF \times BW)}.\]

and Rp. The Following equation can be utilized to obtain the PSS shunt fraction. Rp and Rs values as obtained above were utilized in this formula.

An example calculation utilizing these formulas is as follows: A 3kg Maltese had a PSS operation and the following PVP and PVP' were obtained: portal venous pressure before

\[PVP = (PVP' - PVP) \times BW \times \frac{R_p}{(PVP/PVBF \times BW)}\]
PSS ligation (PVP) was 4 mmHg; portal venous pressure after PSS ligation (PVP') was 12 mmHg; PSS fraction (%) = 100 – (100 × 4)/12 = 67.

Thus, the shunt fraction can be easily obtained by utilizing a simple calculation utilizing portal pressure before and after the shunt ligation. This formula has been applied to PSS cases which had either complete or partial ligation. The calculated shunt fractions were analyzed in each group. The case profile includes breed of dogs, age at the surgery, portal pressure, temporary complete shunt ligation pressure and shunt fraction (Table 1).

The PSS cases were divided into two groups depending on the portal pressure after the complete ligation of the shunt vessel. The complete ligation group (n=59) was defined if the portal pressure were below 15 mmHg, whereas the partial ligation group (n=48) had the portal pressure were above 16 mmHg at the time of complete ligation. The age at the time of surgery did not have a significant difference between two groups. There were no significant differences in portal pressure before ligation between the two groups; however, the partial ligation group had a significantly higher portal pressure during temporary complete occlusion than complete ligation group. The calculated shunt fraction was 48.2 ± 16.9 % and 71.6 ± 10.7 % in complete and partial ligation group respectively.

Thus, the shunt fractions were obtained by simple calculation utilizing measured portal pressure before and after the shunt ligation at the time of surgery. This method is simple and does not require any regulated isotope substances. The control study to verify the accuracy of the shunt fraction by this method comparing with the isotope study could not be done since the cases were all clinical cases and the isotope are not available in Japan, however, the method should be verified by the research center where the isotopes are utilized.

One Yorkshire terrier case had two surgeries: at the first operation, the shunt fraction was 70.0% and the portal pressure at the time of complete ligation was 28 mmHg and the shunt was closed at the portal pressure was 14 mmHg; 4 month after the first operation, the shunt vessel could be completely ligate (portal pressure: 12 mmHg) and the shunt fraction was 41.7%. If a patient has higher shunt fraction, the portal pressure at the time of complete ligation would be higher: higher the portal pressure, higher the shunt fraction. The partial ligation group which had a higher shunt fraction have higher incidence of recurrence rate of clinical signs of hepatic failure than complete ligation group which had a
better prognosis [7]. Kaplan Mayer analysis for survival length was evaluated in each group [9]. The complete ligation group lived longer than the partial ligation group which will be reported separately from this study. Thus, the shunt fraction would be one of the indices of estimating the prognosis of PSS surgery.

REFERENCES


<table>
<thead>
<tr>
<th>age (month)</th>
<th>P.P.(mmHg)</th>
<th>P.P.T.C.S.L. (mmHg)</th>
<th>S.F (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete ligation</td>
<td>n=59</td>
<td>22.4 ± 23.6</td>
<td>5.8 ± 2.0</td>
</tr>
<tr>
<td>Partial ligation</td>
<td>n=48</td>
<td>22.3 ± 15.1</td>
<td>6.2 ± 2.3</td>
</tr>
</tbody>
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m ± SD: mean ± standard deviation. P.P.: Portal pressure before ligation, P.P.T.C.S.L: Portal pressure of temporary complete shunt ligation, S.F.: shunt fraction, ** p>0.01.