Portal vein pulsatility index is a more important indicator than congestion index in the clinical evaluation of right heart function

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**Abstract**

**AIM:** To study the changes of portal blood flow in congestive heart failure.

**METHODS:** We studied the congestion index (CI) and portal vein pulsatility index (PI) in patients with varied degrees of congestive heart failure using ultrasonic Doppler. Ten patients with mean right atrial pressure (RA) < 10 mmHg were classified as group 1 and the remaining 10 patients with RA ≥ 10 mmHg as group 2.

**RESULTS:** There was no difference on cardiac index (HI, \(P = 0.28\)), aortic pressure (AO, \(P = 0.78\)), left ventricular end-diastolic pressure (LVED, \(P = 0.06\)), maximum portal blood velocity \((V_{\text{max}}, P = 0.17)\), mean portal blood velocity \((V_{\text{mean}}, P = 0.15)\) and portal blood flow volume (PBF, \(P = 0.95\)) between the two groups. Group 2 patients had higher pulmonary wedge pressure (PW, 29.9 ± 9.3 mmHg vs 14.6 ± 7.3 mmHg, \(P = 0.002\)), pulmonary arterial pressure (PA, 46.3 ± 13.2 mmHg vs 25.0 ± 8.2 mmHg, \(P = 0.004\)), RA (17.5 ± 5.7 mmHg vs 4.7 ± 2.4 mmHg, \(P < 0.001\)), right ventricular end-diastolic pressure (RVED, 18.3 ± 5.6 mmHg vs 6.4 ± 2.7 mmHg, \(P < 0.001\)), CI (8.7 ± 2.4 vs 5.8 ± 1.2, \(P = 0.03\)), and PI (87.8 ± 32.3% vs 27.0 ± 7.4%, \(P < 0.001\)) than Group 1. CI was correlated with PI (\(P < 0.001\)), PW (\(P < 0.001\)), PA (\(P < 0.001\)), RA (\(P = 0.043\)), RVED (\(P = 0.005\)), HI (\(P < 0.001\)), AO (\(P < 0.001\)), CO (\(P < 0.001\)), LVED (\(P < 0.001\)), \(V_{\text{max}} (P < 0.001)\), \(V_{\text{mean}} (P < 0.001)\), cross-sectional area of the main portal vein (\(P < 0.001\)) and PBF (\(P < 0.001\)). CI could be as high as 8.3 in patients with RA < 10 mmHg and as low as 5.9 in those with RA ≥ 10 mmHg.

**CONCLUSION:** Our data show that RI is a more significant indicator than CI in the clinical evaluation of high RA ≥ 10 mmHg, whereas CI is better than PI in the assessment of left heart function.

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**Key words:** Portal blood flow; Heart failure; Ultrasonic Doppler; Congestion index; Portal vein pulsatility index

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**INTRODUCTION**

Congestive heart failure increases the pressure in the inferior vena cava and hepatic veins[1-3]. Ultrasonic Doppler is a safe and non-invasive method in the clinical evaluation of portal blood flow and portal hypertension[4-9]. Portal vein pulsatility index (PI) is calculated by the percentage of peak-to-peak maximum portal vein velocity[10,11]. In our earlier study[10], patients with right heart failure developed transient reduced, stagnant, or hepatofugal portal blood flow with increased PI. However, the change of portal flow pattern and PI did not correlate with left heart function.

The congestion index (CI) has been used to assess the pathophysiological hemodynamics of portal venous system in different forms of liver diseases[12-14]. The correlation between CI and PI and the role of CI on right heart function remain uncertain. Therefore, we have studied the changes of portal blood flow in patients with different degrees of heart failure using non-invasive ultrasonic Doppler[15-16].

**MATERIALS AND METHODS**

We studied the portal hemodynamic profiles in 20 patients (9 males, 11 females, mean age: 49 ± 13 years) who received cardiac and Swan-Ganz catheterizations for cardiovascular disorders (16 rheumatic heart disease, 4 atherosclerotic heart disease) to compare with 20 healthy volunteers. All
patients had medications affecting the hemodynamics such as isosorbide dinitrate and furosemide, and their systemic blood pressure and body weight were measured to be constant for more than 48 h prior to the study. Patients with fever, infection, and shock were excluded. All patients had no history of liver disease, alcoholism or other metabolic disorders. None of the patients received transfusion, inotropic agents or dopamine. All patients had an abdominal disorders. None of the patients received transfusion, inotropic agents or dopamine. All patients had an abdominal

injection as appropriate. The study protocol was reviewed and approved by the Institutional Review Committee under the guidelines of the 1975 Declaration of Helsinki. Statistical analysis was performed using Student’s t-test and simple linear regression as appropriate.

RESULTS

The biochemical data of the 20 patients (Table 1) showed total protein 7.0 ± 0.8 g/dL, albumin 3.8 ± 0.5 g/dL, total bilirubin 1.3 ± 0.6 mg/dL, AST 49.5 ± 23.4 IU/L, ALT 28.7 ± 10.4 IU/L, and prolonged prothrombin time 1.2 ± 0.9 s (normal < 3 s). All controls had normal blood chemicals. Gender (P=0.11), age (P=0.61), total protein (P=0.85), albumin (P=0.62), total bilirubin (P=0.83), ALT (P=0.15) and prolonged prothrombin time (P=0.19) were not different between those with RA < 10 mmHg and ≥ 10 mmHg. Patients with RA ≥ 10 mmHg had higher serum AST activities (P=0.009), which were related to ischemic hepatitis.

HI (3.0 ± 0.9 L/min/m²; range: 1.6-5.3 L/min/m² vs 2.4 ± 0.4 L/min/m²; range: 1.7-2.9 L/min/m²; P=0.28), AO (89.0 ± 9.6 mmHg; range: 85-100 mmHg vs 78.3 ± 12.8 mmHg; P=0.06), PW (14.6 ± 5.6 mmHg; range: 9.7-17.7 mmHg; P=0.002), PA (25.0 ± 6.8 mmHg; range: 24.2 ± 12.0 mmHg; P=0.004), RA (4.7 ± 2.1 mmHg; range: 16.8 ± 4.9 mmHg; P=0.001), and RVED (6.4 ± 2.1 mmHg; range: 17.8 ± 4.4 mmHg; P=0.001) were within the normal range.

The portal profiles were assessed using an ultrasonic Doppler. portal blood velocity, antegrade or retrograde, was also measured. Positive velocity indicates the blood flow towards the transducer and vice versa. Portal blood flow volume (PBF, mL/min) was obtained by the equation “PBF = area × V_{mean} × 0.686” [16]. PI was calculated by the equation “PI = (maximum-minimum)/maximum frequency shift” [16,17]. The waveforms were classified as continuous (PI ≤ 40%), decreased (PI 41-99%), stagnant (PI = 100%), or retrograde (PI > 100%). CI was calculated by the equation “CI = ([area]/[V_{mean}]) × 0.686” [18].

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For all Group 1 patients, the values of PW (mean: 14.6 ± 5.6 mmHg; range: 5-28 mmHg), PA (mean: 25.0 ± 6.8 mmHg; range: 16-38 mmHg), RA (mean: 4.7 ± 2.1 mmHg; range: 1.7 mmHg), and RVED (mean: 6.4 ± 2.1 mmHg; range: 2-11 mmHg) were within the normal range.
Portal vein pulsatility index of patients with right atrial pressure <10 mmHg (Group 1) and ≥10 mmHg (Group 2).  

**DISCUSSION**

It is well known that the passive “backward” congested liver develops into hepatomegaly, synchronous pulsation, engorged and dilated terminal hepatic veins, atrophy of hepatocytes and eventually cardiac cirrhosis. The high hepatic vein pressure can transmit through the liver to cause post-sinusoidal portal hypertension, cardiac ascites and change of portal flow pattern(s). Therefore, the changes of portal flow may help the assessment of heart function.

Prolonged right heart failure may result in atrophy of hepatocytes and eventually cardiac cirrhosis. In the present study, we have strived to exclude those patients with chronic liver disease. The abdominal sonographies showed no splenomegaly or coarse liver echogenicity and the peripheral blood showed no abnormal reduction of leukocyte, hemoglobin or platelet account, which were common in cirrhosis. Furthermore, the portal flow pattern did not show reduced fluctuation, which was common in cirrhosis with portal hypertension. Our patients were not likely to develop obvious cardiac cirrhosis.

In the present study, all patients with RA ≥10 mmHg had a PI > 40% and all patients with RA <10 had a PI <40% or less. The findings were consistent with our prior study(1) that PI showed a good correlation with PW, PA, RA, and RVED. The waveform changes of portal blood flow correlate well with right heart function, and the measurement of PI change is a simple and non-invasive method.
invasive method to identify right heart failure. Our data also demonstrated that PI had no any correlation with HI, AO, CO, LVED, V\textsubscript{max},\ V\textsubscript{mean} and PBF. Furthermore, the waveform changes of portal blood flow correlated well with right heart function; and the PI is helpful for the diagnosis of stagnant or hepatofugal portal blood flow but not by the CI. Therefore, CI is better than PI in the assessment of left heart function.

In addition to the assessment of left heart function, the CI correlated with all PBF, V\textsubscript{max}, V\textsubscript{mean}, area, PI, HI, PW, PA, RA, AO, CO, LVED, and RVED. These results suggest that CI also correlates well with right heart profiles. Our findings were consistent with earlier studies. However, the CI values could be as high as 8.3 in patients with RA < 10 mmHg and as low as 5.9 in those with RA ≥ 10 mmHg. If the CI value is between 5.9 and 8.3, it is difficult to predict whether or not the RA values ≥ 10 in patients with RA < 10 mmHg.

The occurrence of congestive liver is not uncommon in patients with congestive heart failure. In addition to the occurrence of congestive hepatomegaly and dilatation of inferior vena cava and hepatic veins during abdominal sonography, the measurement of both CI and PI is helpful for the indirect non-invasive evaluation of cardiac function.

REFERENCES

1. Pannen BH. New insights into the regulation of hepatic blood flow after ischemia and reperfusion. Anesth Analg 2002; 94: 1448-1457
2. Shen B, Younossi ZM, Dolmatch B, Newman JS, Henderson JM, Ong JP, Gramlich T, Yamani M. Patent ductus venosus in an adult presenting as pulmonary hypertension, right-sided heart failure, and portosystemic encephalopathy. Am J Med 2001; 110: 657-660
3. Giallourakis CC, Rosenberg PM, Friedman LS. The liver in heart failure. Clin Liver Dis 2002; 6: 947-67, viii-ix
4. Ohnishi K, Saito M, Sato S, Sugita S, Tanaka H, Okuda K. Clinical utility of pulsed Doppler flowmetry in patients with portal hypertension. Am J Gastroenterol 1986; 81: 1-8
5. Shapiro RS, Stancato- Pasik A, Glajchen N, Zalasins S. Color Doppler applications in hepatic imaging. Clin Imaging 1998; 22: 272-279
6. Yang SS, Wu CH, Huang CS, Ho MS, Lai MY, Kao JH, Chen DS. Early interferon therapy and abortion of posttransfusion hepatitis C viral infection. J Clin Gastroenterol 1995; 21: 38-41
7. Yang SS, Ralls PW, Koura J. The effect of oral nitroglycerin on portal blood velocity as measured by ultrasonic Doppler. A double blind, placebo controlled study. J Clin Gastroenterol 1991; 13: 173-177
8. Gorka W, Gorka TS, Lewall DB. Doppler ultrasound evaluation of advanced portal vein pulsatility in patients with normal echocardiograms. Eur J Ultrasound 1998; 8: 119-123
9. Killi RM. Doppler sonography of the native liver. Eur J Radiol 1999; 32: 21-35
10. Hu JT, Yang SS, Lai YC, Shih CY, Chang CW. Percentage of peak-to-peak pulsatility of portal blood flow can predict right-sided congestive heart failure. World J Gastroenterol 2003; 9: 1828-1831
11. Hosoki T, Aritsawa J, Marukawa T, Tokunaga K, Kuroda C, Kozuka T, Nakano S. Portal blood flow in congestive heart failure: pulsed duplex sonographic findings. Radiology 1990; 174: 733-736
12. Moriyasu F, Nishida O, Ban N, Nakamura T, Sakai M, Miyake T, Uchino H. “Congestion index” of the portal vein. AJR Am J Roentgenol 1986; 146: 735-739
13. Merkel C, Sacerdoti D, Bolognesi M, Bombonato G, Gatta A. Doppler sonography and hepatic vein catheterization in portal hypertension: assessment of agreement in evaluating severity and response to treatment. J Hepatol 1998; 28: 622-630
14. Moriyasu F, Nishida O, Ban N, Nakamura T, Miura K, Sakai M, Miyake T, Uchino H. Measurement of portal vascular resistance in patients with portal hypertension. Gastroenterology 1986; 90: 710-717
15. Koslin DB, Mulligan SA, Berland LL. Duplex assessment of the portal venous system. Semin Ultrasound CT MR 1992; 13: 22-33
16. Bolondi L, Giani S, Barbara L. Accuracy and reproducibility of portal flow measurement by Doppler US. J Hepatol 1991; 13: 269-273
17. Sabbà C, Weltin GG, Cicchetti DV, Ferraioli G, Taylor KJ, Nakamura T, Moriyasu F, Groszmann RJ. Observer variability in echo-Doppler measurements of portal flow in cirrhotic patients and normal volunteers. Gastroenterology 1990; 98: 1603-1611
18. Moriyasu F, Ban N, Nishida O, Nakamura T, Miyake T, Uchino H, Kanematsu Y, Koizumi S. Clinical application of an ultrasonic duplex system in the quantitative measurement of portal blood flow. J Clin Ultrasound 1986; 14: 579-588
19. Catalano D, Caruso G, DiFazio S, Carpenteri G, Scalsi N, Trovato GM. Portal vein pulsatility ratio and heart failure. J Clin Ultrasound 1998; 26: 27-31
20. van Langen H, van Driel VJ, Skotnicki SH, Verheugt FW. Alterations in the peripheral circulation in patients with mild heart failure. Eur J Ultrasound 2001; 13: 7-15
21. Rengo C, Brevetti G, Sorrentino G, D’Amato T, Imparato M, Vitale DF, Acanfora D, Rengo F. Portal vein pulsatility ratio provides a measure of right heart function in chronic heart failure. Ultrasound Med Biol 1998; 24: 327-332

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