Portal Venous Pulsatility Fraction, a Novel Transesophageal Echocardiographic Marker for Right Ventricular Dysfunction in Cardiac Surgical Patients

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Abstract

Background: Right ventricular (RV) has a vital role in maintaining optimal tissue perfusion. Assessment of portal venous flow characteristics can be alternative and emerging technique to assess RV function. **Aims:** To investigate if portal venous pulsatility fraction (PF) could serve as effective and complementary tool in identifying RV dysfunction. **Materials and Methods:** Thirty adult patients aged 18-65 years undergoing cardiac surgery under general anesthesia were enrolled in study. Intraoperative transesophageal echocardiographic examination was performed. Tricuspid annular plane systolic excursion (TAPSE), RV fractional area change (FAC), RV ejection fraction (EF), and portal vein flow pulsatility were assessed. Portal vein PF was used to quantify degree of pulsatility. **Results:** Portal vein was demonstrated in 27 patients (90%). 27 values of portal vein PF, RV EF, FAC, and TAPSE were analyzed. Portal vein PF demonstrated significant linear correlation with TAPSE ($r = -0.55$, $P = 0.003$), RV FAC ($r = -0.44$, $P = 0.02$), and RV EF ($r = -0.53$, $P = 0.004$). ROC curve was constructed to calculate sensitivity and specificity of portal vein PF for assessing RV function. Portal vein PF value of ≥45% indicated RV dysfunction with sensitivity of 92.3%, specificity of 71.4%, positive predictive value of 75%, and negative predictive value of 90.9%. Area under ROC curve was 0.819 (95% confidence interval = 0.624 – 0.939, $P = 0.0006$). **Conclusion:** Portal vein PF is simple and feasible method for assessment of RV function. It complements the existing echocardiographic measures to diagnose RV dysfunction.

Keywords: *Portal vein pulsatility fraction, RV ejection fraction, RV fractional area change, RV function, Tricuspid annular plane systolic excursion, transesophageal echocardiography*

Introduction

Right ventricular (RV) function has a vital role in maintaining optimal tissue perfusion. However, RV function is not well understood and hence least investigated as compared to left ventricular function. In cardiac surgical patients, RV dysfunction is associated with organ hypoperfusion and venous congestion leading to increased morbidity and mortality.[1] The lack of accurate investigating tools to assess RV function has complicated the present scenario. Several non-invasive and invasive methods have been described for measuring RV function. Non-invasive methods used to assess RV function are 2D-echocardiographic measurement of tricuspid annular plane systolic excursion (TAPSE), RV ejection fraction (EF), RV fractional area change (FAC), 3D assessment of RV function, tissue Doppler assessment of velocities, and magnetic resonance imaging (MRI). Though MRI is the gold standard method to assess RV function, it cannot be used in the perioperative period. Invasive methods of RV function assessment are cumbersome to perform. The authors have hypothesized an alternative and simple echocardiographic technique to assess RV function based on Doppler flow patterns of the portal vein. This hypothesis is based on previous retrospective studies using portal venous flow to assess end organ venous congestion and organ dysfunction in cardiac patients. In the present prospective observational study, the authors have investigated the correlation between the pattern of portal venous flow and RV function as assessed by 2D transesophageal echocardiography (TEE) in the intraoperative period.

Materials and Methods

After obtaining informed consent from all patients, 30 adult patients aged 18–65 years

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undergoing cardiac surgery under general anesthesia (GA) were enrolled in the study. This was a prospective observational study conducted in a tertiary care hospital. Patients with primary liver pathology, arrhythmias, use of ventricular pacing, use of tricuspid valve annuloplasty ring, and contraindications for TEE probe placement were excluded from the study. A 5 MHz multiplane TEE probe (Philips En Visor CHD, Bathell, WA) was inserted after induction of GA and TEE was performed in all patients. After a comprehensive echocardiographic examination, TAPSE, RV FAC, RV EF, and portal vein flow pulsatility were assessed. TAPSE was measured in deep transgastric in/outflow view whereas RV FAC and RV EF were measured in midesophageal 4 chamber view. To obtain an image of portal venous flow using TEE, a view of inferior venacava is obtained using a lower midesophageal view with the omniplane transducer at 90°. The TEE probe is then slowly advanced in a transgastric position while maintaining the liver under the ultrasound beam. The multiplane angle rotation between 50° and 70° will typically align the right portal vein with the centre of the ultrasound beam.[2] Pulsed wave doppler beam is aligned along the portal vein and the velocity of portal venous flow assessed at end expiration [Figure 1].

The portal vein pulsatility fraction (PF) is used to quantify the degree of pulsatility. PF is calculated as PF (%) = 100 [(Vmax - Vmin)]/ (Vmax), where Vmax is the maximal blood velocity and Vmin is the minimal blood velocity of portal vein during cardiac cycle.

RV dysfunction is defined as TAPSE <15 mm, RV FAC is <35% and RV EF <45%.[3]

In the study, RV dysfunction was considered to be present if either of the two parameters were found abnormal.

Statistical analysis

Normal distribution was done using Kolmogorov – Smirnov test. Correlation between portal vein PF and RV function was performed using Pearson correlation coefficient (r). Receiver operating characteristic (ROC) curve was constructed to calculate sensitivity and specificity. Statistical analysis were done using MedCalc. A *P* value <0.05 was considered significant.

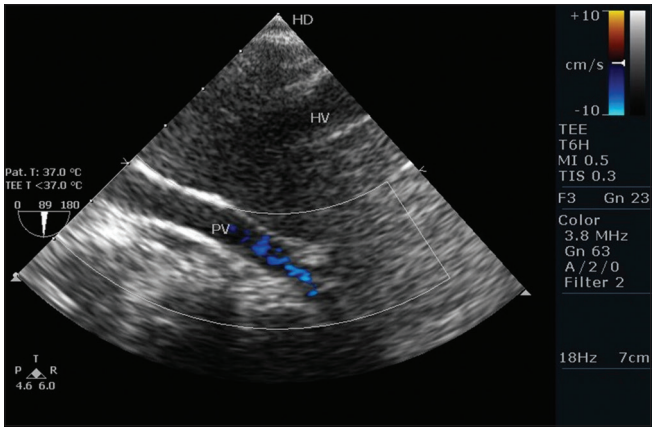

Figure 1: Figure demonstrating portal vein flow

Results

Thirty adult patients undergoing cardiac surgery were enrolled in the study [Table 1], portal vein could be demonstrated in 27 patients (90%). A total of 27 values of portal vein PF, RV EF, FAC, and TAPSE were analyzed. The portal vein PF demonstrated significant inverse correlation with TAPSE (r = −0.55, confidence interval = −0.7682 to −0.2126, *P* = 0.003), RV FAC (r = −0.44, confidence interval = −0.7042 to −0.07625, *P* = 0.02) and RV EF (r = −0.53, confidence interval = −0.7594 to −0.1921, *P* = 0.004) [Table 2]. PF value of ≥45% indicated RV dysfunction with a sensitivity of 92.3%, specificity of 71.4%, positive predictive value of 75%, negative predictive value of 90.9%, positive likelihood ratio of 3.23 and negative likelihood ratio of 0.11. Area under the ROC curve was 0.819 (95% confidence interval = 0.624 – 0.939, *P* = 0.001) [Figure 2].

Discussion

RV dysfunction is one of the causes of morbidity and mortality in cardiac surgical patients. RV function assessment is mostly limited to qualitative visual assessment intraoperatively.[4] Echocardiographic variables such as TAPSE, RV FAC, and RV EF are routinely used intraoperatively to assess RV function. The more complex measurements to grade the systolic function such as RV strain and 3D EF are not included in the basic perioperative TEE guidelines.[5] Portal venous pulsatility is a known method described for assessment of portal hypertension in cirrhotic patients. Normal portal flow assessment by pulsed wave doppler are monophasic or biphasic. Variations in portal venous flow during the cardiac cycle are due to the transmission of hepatic

Table 1: Demographic data

Variable	Mean±S.D
Age (Years)	45.3±14.38
Height (m)	1.62±0.078
Weight (Kg)	62±8.64
BMI (Kg/m^2)	23.4±3.12

Values are mean±SD

Table 2: Correlation between portal vein pulsatility fraction and RV function

Variable	*r*	95% CI	*P*
TAPSE	-0.55	-0.7632--0.2126	0.003
RV FAC	-0.44	-0.7042--0.07625	0.02
RV EF	-0.53	-0.7594--0.1921	0.004

TAPSE: Tricuspid annular plane systolic excursion; RV: Right ventricle; FAC: Fractional area change; EF: Ejection fraction; CI: Confidence interval

venous pressure through the liver sinusoids.[6] When the right atrial pressure is increased, variations in portal venous flow during the cardiac cycle may be more pronounced. A normal portal vein flow velocity has minimal pulsatility [Figure 3], indicating normal RV function as measured by TAPSE, RV FAC, and RV EF. Increased pulsatility of portal venous flow [Figure 4] was found to correlate with RV dysfunction. Variations in portal venous flow during cardiac cycle are due to transmission of hepatic venous pressures through the hepatic sinusoids. In the present study it was feasible to demonstrate the portal venous flow with a success rate of 90%. It was observed that with an increase in the portal vein PF there was a deterioration of RV function. The constructed ROC curve demonstrated an area under the curve of 0.819 (P = 0.001).

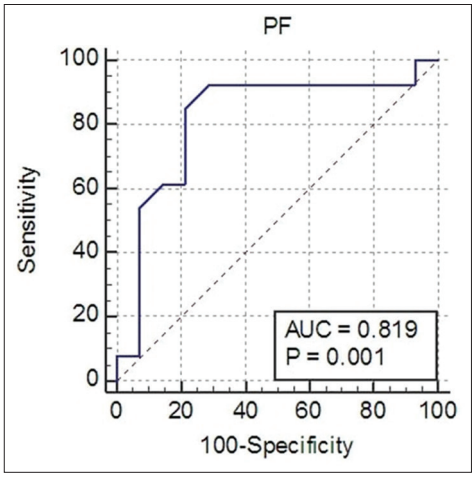

Figure 2: Area under the ROC curve to correlate portal vein PF and RV function

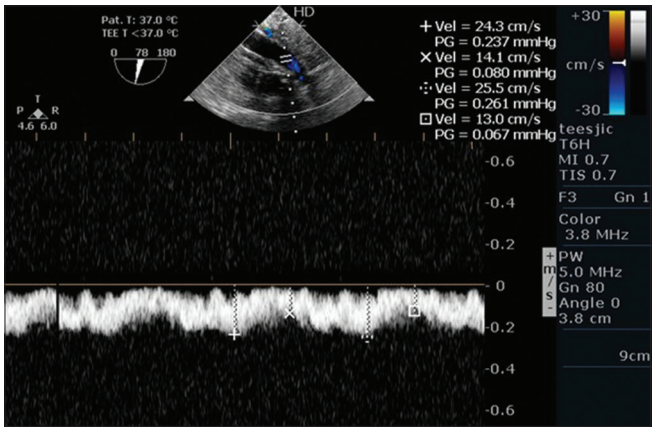

Figure 3: Portal vein flows demonstrating minimal pulsatile flows

Denault *et al*.,[2] in an editorial has demonstrated the method to obtain portal vein flows using TEE and concluded saying that increased pulsatility of portal vein flows indicates venous congestion. In the present study a portal vein PF of ≥45% signified presence of RV dysfunction.

Shih *et al*.[7] demonstrated a PF of >87.8% ± 32.3% in patients with right atrial pressures (RAP) of >10 mmHg and a PF of 27 ± 7.4% when RAP were ≤10 mmHg.

Hu JT *et al*.[8] demonstrated a PF of >40% indicated right heart failure in post cardiac catheterization patients as indicated by RAP >10 mmHg.

In both the above-mentioned studies, the RAP was correlated with portal vein pulsatility to predict right heart function.

In the present study the authors have used more specific RV parameters to assess RV function. The authors have obtained a portal vein PF of ≥45% as a tool to diagnose RV dysfunction.

Denault *et al*.[9] reported a PF of 75.35 ± 23.38% indicated RV dysfunction in a case series of 14 patients, of whom 9 patients were assessed by TTE and 5 patients with TEE.

In the present study all the patients were assessed uniformly with TEE and obtained a PF of ≥45% as a marker of RV dysfunction with a sensitivity of 92.3%, specificity of 71.4%, positive predictive value of 75%, negative predictive value of 90.9%, positive likelihood ratio of 3.23, and negative likelihood ratio of 0.11.

The evaluation of portal vein PF was not correlated with the gold standard MRI and 3D assessment of RV function being the limitation of the study.

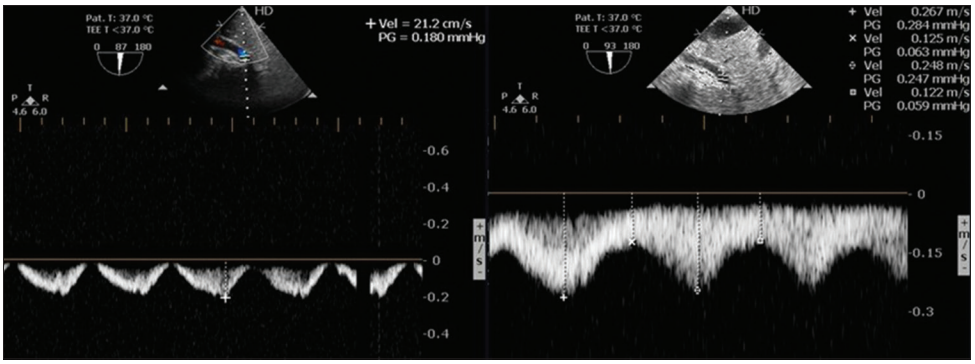

Figure 4: Figure demonstrating pulsatile portal flows

Conclusion

The portal vein PF is a simple and feasible method and complements the existing 2D echocardiographic measures to assess the RV function.

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Conflicts of interest

There are no conflicts of interest.

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