Pulmonary Windkessel Volume and Resistance Parameters in Patients with Pulmonary Hypertension Using MR Phase Contrast Imaging

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Introduction

Pulmonary vascular resistance (PVR) is recognized as a useful hemodynamic index for diagnosing patients with pulmonary hypertension (PH). The invasive cardiac catheterization procedure is currently the clinical standard to determine the severity of the PH. A noninvasive method that can provide a reliable index to differentiate patients with PH from healthy people would be helpful for clinical diagnosis. It has been demonstrated that some indices derived by phase-contrast MRI (PCMRI) were highly correlated with PVR [1]. Besides, it was shown in our previous study [2] that PH patients had significantly greater windkessel volume (V_{wk}) [3] of pulmonary vessels than normal volunteers. V_{wk} stands for a hemodynamic index that describes the reservoir and wave-transmitting properties of the blood vessels, represented by the mean difference of volume between inflow (Vin) and outflow (Vout) during a cardiac cycle. In this study, we will compare these hemodynamic indices related to PVR and V_{wk}, and investigate their sensitivity to differentiate patients with PH from normal group.

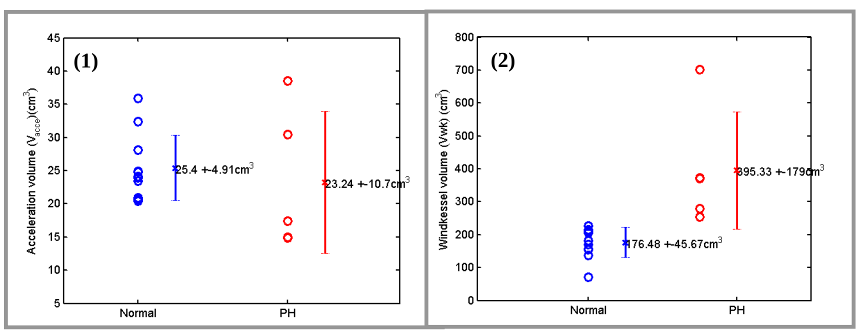
Materials and Methods

Our study population consisted of 5 patients with PH (female:1; male:4; age: 55±16 yrs; pulmonary pressure with catheterization: 64±31 mmHg) and 11 healthy subjects without history of pulmonary disease (female: 7; male: 4; age: 39±9 years). Phase contrast MRI was performed on a 1.5T clinical imager (Siemens Sonata, Erlangen, Germany) using the torso coil with ECG gating. A 2D FLASH sequence (TR/TE=22/4.8 ms, flip angle=15^0) with 150cm/sec velocity-encoding gradient was repeated two times with trigger delay of 0, 11 ms from the R wave, sampling 90% of the cardiac cycle. Flows (Q) were derived for each cardiac phase, with the cross-sectional area determined by manually outlining of the vessels. V_{wk} was calculated according to our previous study [2]. Other two PVR-related hemodynamic parameters [1], acceleration volume (V_{acce}) and maximal change in flow rate during ejection (max. dQ/dt), were also calculated. To compare the PVR-related parameters and V_{wk}, the ratio of them were calculated. As shown in Table 1, Ratio1 was the ratio of max. dQ/dt to V_{acce} [1] and Ratio2 was the ratio of V_{wk} to V_{acce}.

Table 1. Hemodynamic parameters of patients and healthy group.

	Sex/ Age(ys)	PAP (mmHg)	Cardiac output (cm^3/s)	V_{acce} (cm^3)	max. dQ/dt (cm^3/sec^2)	V_{wk} (cm^3)	Ratio 1 (sec^{-2})	Ratio 2
Patient with PH (N=5)								
1	F/45	100	42.8	14.9	4190	371.8	280.1	24.9
2	M/73	50	43.5	17.4	6073	370.2	349.0	21.3
3	M/46	43	52.3	14.9	4276	278.9	287.9	18.8
4	M/72	NA	79.8	38.5	14777	701.0	383.5	18.2
5	M/38	NA	92.5	30.5	4862	254.7	159.6	8.4
Mean	55	64.3	62.2	23.2	6835.6	395.3	292	18.3
±SD	±16	±31	±22.6	±10.7	±4502	±178.8	±85.6	±6.1
Healthy subjects (N=11)								
Mean	39	NA	70.1	25.4	3981.9	176.5	154.1	7.12
±SD	±9.4		±11.7	±4.9	±1216.4	±45.7	±24.1	±2.2
p-value			NS	NS	<0.05	<0.001	<0.001	<0.001

Ratio1 = (max. dQ/dt)/acceleration volume; NA: data not available; p-value: Student's t-test
Ratio2 = windkessel volume (V_{wk})/ acceleration volume (V_{acce}); NS: not statistic significant



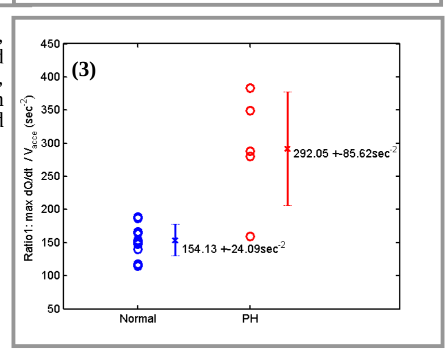


Fig.1-3. The values of acceleration volume, windkessel volume and Ratio1 of normal and PH patients group. As shown in these figures, V_{wk} successfully differentiates patients with PH from healthy subjects, while V_{acce} and Ratio1 cannot.

Results

Table 1 listed several hemodynamic parameters. The difference of V_{acce} between patients with PH and 11 healthy subjects were not statistical significant (Fig.1). However, the other PVR-related parameter, Ratio1, in patients were significantly greater than in healthy subjects (292±85.6 vs. 154.1±24.1sec^{-2}, $p<0.001$). V_{wk} were 395.3±178.8 and 176.5±45.7 cm^3 in PH patients and healthy subjects ($p<0.001$), respectively (Fig.2). The value of Ratio2 from the PH patients was 18.3±6.1, significantly greater than the value of 7.2±2.2 obtained from healthy subjects ($p < 0.001$).

Conclusion

The PVR-related parameter, V_{acce}, fails to differentiate two of our PH patients, case 4 and 5, from normal group. This may be related to the fact that these patients presented with larger cardiac output or larger flow rate. In contrast, V_{wk} is less affected by a subject's flow rate, thus more sensitive than V_{acce} in diagnosing PH. Case 5 also presents with a lower value of Ratio1 (Fig.3). However, he has a relatively higher V_{wk} and Ratio2 than the healthy subjects (Table1). This implies that V_{wk} and Ratio2 could differentiate PH from normal group more accurately. In conclusion, we have used phase-contrast MRI to noninvasively evaluate pulmonary windkessel volume and resistance in patients with PH. The parameters based on windkessel volume have better differentiation power than the PVR-related parameters. A larger patient population is certainly necessary for further investigations.

References

1. Mousseaux et al. Radiology 1999; 212:896-902. 2. Peng et al., 12th ISMRM 2004, Toronto, Canada; In Proceeding: p355. 3. Wang et al. Am J Physiol Heart Circ Physiol 2003; 284:H1358.