Analysis of the Hemodynamic Parameters of Patients with Pulmonary Arterial Hypertension by MR Phase-Contrast Imaging

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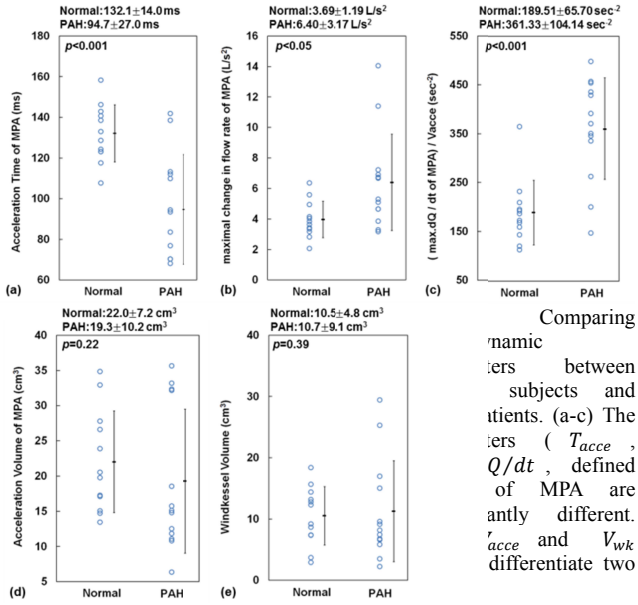
Introduction: Patients with pulmonary hypertension (PH) usually present an increase in blood pressure in pulmonary arteries, pulmonary veins, or pulmonary capillaries. Symptoms such as short and rapid breaths, dizziness, faintness, and so on, are exacerbated while doing exercise. Pulmonary hypertension can be a severe disease with a markedly decreased tolerance of exercise and heart failure [1]. The subjects included in this study are patients with pulmonary arterial hypertension (PAH) which is one of the five categories of PH. Before the treatment of PAH-related diseases, clinicians may have to evaluate patients' severity at first. Non-invasive phase-contrast MR imaging (PC-MRI) is a convenient method for diagnosis. In previous study, non-invasive PC-MRI has been used to provide reliable hemodynamic parameters [2]. Hemodynamic parameters of patients with PH have been proved with high correlation coefficients. The hemodynamic parameters including acceleration time and arterial distensibility, measured by non-invasive PC-MRI and invasive catheterization methods, were significantly different between patients with primary pulmonary hypertension (PPH) and volunteers (p<0.05) [3]. Windkessel volume (V_{wk}), a quantified parameter of windkessel effect, accounted for the shape of the arterial pressure waveform, has been used to describe the reservoir in aortic artery in animal experiment [4]. It is calculated by integrating the measurement inflow (V_{in}) and outflow (V_{out}) during a cardiac cycle [4]. Moreover, it has been demonstrated that some indices derived by PC-MRI were highly correlated with pulmonary vascular resistance (PVR) [2]. In this study, we aim to acquire V_{wk} and other hemodynamic parameters to investigate differences between normal subjects and patients with PAH.

Materials and Methods: The study population consisted of 13 PAH patients (male:6; female:7; age:42±17 y/o) and 12 normal subjects without history of pulmonary disease (male:5; female:7; age:39±9 y/o). PC-MRI was performed on a 1.5T clinical imager (Siemens Sonata, Erlangen, Germany) using the torso coil with prospective ECG triggering. A 2D FLASH sequence (TR/TE=22/4.8ms, flip angle=15°) with 150 cm/sec velocity-encoding gradient was acquired, sampling 90% of the cardiac cycle. Magnitude images and phase images were obtained by using PC-MRI at main pulmonary artery (MPA), right pulmonary artery (RPA) and left pulmonary artery (LPA). The regions of interest (ROI) of cross-section of above vessels were selected manually on magnitude images and were applied to phase images for calculation of flow velocity. Several hemodynamic parameters were calculated: V_{wk}, the time from the onset of flow to the peak flow rate (acceleration time (T_{acce})), acceleration volume (V_{acce}), maximal change in flow rate during ejection (max.dQ/dt), and the ratio of max. dQ/dt to V_{acce}. Student's t-test was used to comprehend the significance of the difference between normal subjects and PAH patients.

Results: Fig. 1 showed the calculated hemodynamic results of MPA. The T_{acce} of MPA in PAH patients and normal subjects were 94.7±27.0 ms and 132.1±14.0 ms, respectively (p<0.001). The values of max.dQ/dt of two groups were 6.40±3.17 and 3.69±1.19 L/s^2 (p<0.05), respectively. The mean value of the defined ratio in patients' MPA was 361.33±104.14, significantly greater than that obtained from normal subjects (189.51±65.70; p<0.001). However, in our preliminary results, the differences of values of V_{acce} of MPA and V_{wk} between two groups were not statistically significant. Table 1 listed all hemodynamic parameters of two groups. The parameters of T_{acce}, max.dQ/dt and the defined ratio were statistically significant between two groups at not only MPA but also at RPA and LPA. As for V_{acce} and V_{wk}, there was no significant difference between two groups.



Comparing namic ters between subjects and ıtients. (a-c) The ters (T_{acce}, Q/dt, defined of MPA are antly different. $_{acce}$ and V_{wk} differentiate two

Parameters	Position	Patients with PAH(N=13)	Healthy subjects(N=12)	
		Mean±SD	Mean±SD	p-value
t_{acce} (ms)	MPA	94.7±27.0	132.1±14.0	p<0.001
	RPA	102.4±33.4	148.4±20.4	p<0.001
	LPA	99.8±25.2	136.7±28.6	p<0.01
V_{acce} (cm³)	MPA	19.3±10.2	22.0±7.2	NS
	RPA	7.8±5.4	9.1±2.3	NS
	LPA	4.5±3.0	6.4±1.5	p<0.05
V_{wk} (cm³)		10.7±9.1	10.5±4.8	NS
$max.dQ/dt$ (L/s²)	MPA	6.40±3.17	3.96±1.19	p<0.05
	RPA	2.85±1.66	1.74±0.59	p<0.05
	LPA	1.76±0.89	1.34±0.60	NS
Ratio (sec⁻²)	MPA	361.33±104.14	189.51±65.70	p<0.001
	RPA	433.88±182.46	195.79±70.28	p<0.001
	LPA	468.17±202.06	214.93±98.49	p<0.001

dent's t-test

Discussion and Conclusions: Hemodynamic indices estimated by non-invasive PC-MRI were highly correlated with that measured with invasive catheterization methods [2]. In this study, several hemodynamic parameters were evaluated to non-invasively differentiate PAH from normal group. When the pressure in pulmonary artery is much higher, the cardiac output might be reduced due to the resistance and the T_{acce} might be shortened (Fig. 1(a)). As shown in Fig. 1(b), max. dQ/dt of patients is significantly larger, suggesting that the ascending slope of flow rate is higher in PAH group. In addition, the ratio, defined by (max.dQ/dt)/V_{acce} with a unit of sec^{-2}, implied a physical parameter of force. PAH patients showed higher ratio, suggesting that PAH patients' hearts supplied more power against higher pressure in their pulmonary system. In previous study, V_{wk} has been utilized to estimate the compliance of aortic artery [4]. However, the difference of V_{wk} between two groups is indistinguishable in our preliminary results (Fig. 1(e)). Because of the variety of treatment phases of PAH patients included in this study, the index of V_{wk} may not be robust at present. For further study, it is necessary to recruit a larger population of PAH patients and to group patients into different treatment phases. In conclusion, several hemodynamic parameters can exhibit satisfied performance to differentiation PAH patients from normal groups. In the future, other physiological parameters, such as PVR, can be included to provide more hemodynamic information.

References:

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