Potential hemodynamic biomarkers of pulmonary arterial hypertension measured with an aid of three-dimensional cine phase contrast MR imaging

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PURPOSE

Assessment of pulmonary arterial hypertension (PAH) is drawing more and more attentions from respiratory and cardiovascular clinicians. Pulmonary artery flow velocities, flow volume and their derived parameters, such as acceleration time (AT), acceleration volumes (AV) and maximum flow (MF) vary depending on the degree of pulmonary diseases including PAH [1]. For conclusive assessment of pulmonary arterial pressures, right heart catheterization (RHC) is the gold standard [2]; however, RHC is relatively invasive. Although hemodynamic analysis based on 2D PC MRI is a non-invasive alternative, it requires complicated prospective slice settings and may suffer from slice dependent inconsistent data. The purpose of our study was to assess hemodynamic parameters measured in potential PAH patients with three-dimensional cine phase contrast MR imaging (4D-Flow), and to seek new potential hemodynamic biomarkers that for PAH can be measured simply and objectively.

METHOD AND MATERIALS

The IRB approved prospective study employed 16 consecutive patients who were suspected of suffering from PAH. Blinded to the results of 4D-Flow, RHC was performed in each individuals, and then, 12 non-PAH patients (median age of 74 years old) and 4 PAH patients (median age of 79 years old) were determined according to the RHC data. 4D-Flow was performed by a 3.0T MR Imager (Signa HDx, GEHCJ) with the following parameters of respiratory compensated ECG gated GRE, TR(ms)/TE(ms)/FA(degree) of 5.6/2.8/9, matrix of 256x224, section thickness(mm)of 2, cardiac phase of 20. Velocity encoding (cm/s) of 150, imaging time of 8.2 min. MR fluid dynamic assessments based on 4D-Flow data set with the aid of flow visualization software (Flova2 software; R'tech, Japan). Pulmonary arterial boundary was segmented based on the intensities of both magnitude images and phase images obtained with 4D-Flow. We then calculated and compared the hemodynamic parameters including geometrically averaged systolic wall shear stress (sWSS), mean WSS (mWSS), oscillatory shear index (OSI) and blood vessel section area (BVSA) in the pulmonary artery trunk based on 4D-Flow for all patients. We also created streamline images in pulmonary arteries. For statistical analysis between both groups, the Mann-Whitney U test was used. Moreover, we compared the correlation of regression analysis between hemodynamic parameters and pulmonary arterial pressure (PAP) or BVSA. For the correlation between flow parameters and RHC, the Spearman's rank-correlation coefficient test was used. $P<0.05$ was considered to be significant.

RESULTS

The mean sWSSs of non-PAH and PAH were significantly different (1.034N/m^2 and 0.618N/m^2, respectively; $P<0.01$) (Fig. 1a). The mean OSIs of non-PAH and PAH were also significantly different (0.125% and 0.182%, respectively; $0.01<P<0.05$) (Fig. 1b). The r values of Spearman's rank-correlation coefficient test in comparison between hemodynamic parameters and PAP were -0.62, -0.63 and 0.42 for sWSS, mWSS and OSI respectively (Fig. 2, 3). The r values in comparison between the parameters and BVSA were 0.61 ($P<0.01$) and -0.47 ($0.01<P<0.05$) for sWSS and OSI respectively. Vortex or helical flows were observed in two out of four PAH patients (Fig. 4) but not in any of the non-PAH patients.

DISCUSSION

In this study, there was a statistically significant differences between non-PAH and PAH patients in terms of sWSS and OSI. The sWSS showed inverse and linear correlation to PAP and was linearly related with BVSA. This may be due to decreased pulmonary velocities caused by a dilation of pulmonary artery trunk. OSI was linearly correlated to PAP, which may be due to the vortex or helical flow reflecting disturbed hemodynamics caused by high PAP conditions.

CONCLUSION

The sWSS and OSI measured with an aid of 4D-Flow were considered to be potential hemodynamic biomarkers for PAH diseases.

REFERENCES

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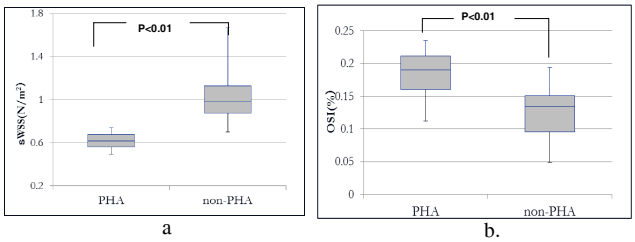

a b.

Figure 1. (a) systolicWSS and (b) OSI were significantly different between PAH and non-PAH.

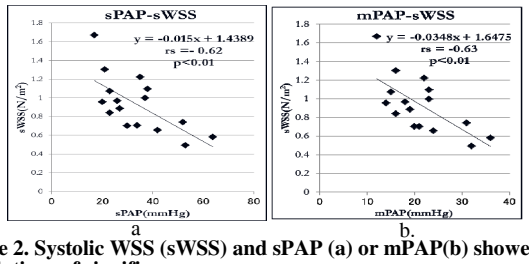

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Figure 2. Systolic WSS (sWSS) and sPAP (a) or mPAP(b) showed linear correlations of significance.

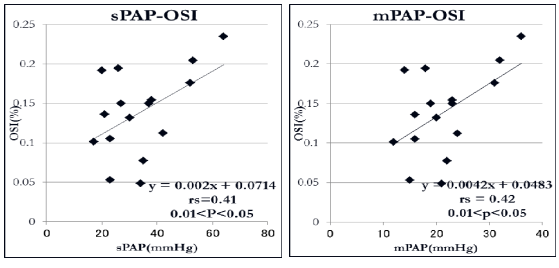

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Figure 3. There were significant inverse correlations between OSI and sPAP (a) or mPAP (b).

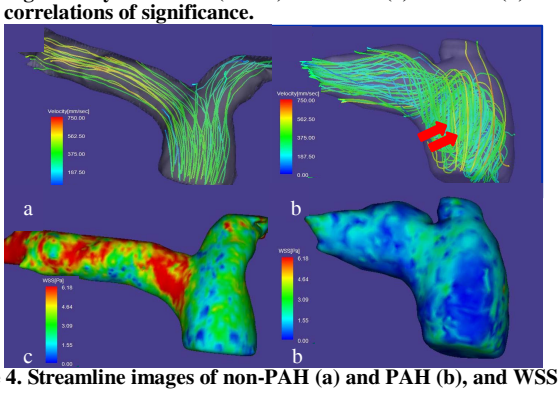

Figure 4. Streamline images of non-PAH (a) and PAH (b), and WSS images of non-PAH (c) and PAH (d). Note helical flow within the dilated main pulmonary trunk.