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4D flow-sensitive MR estimation of pulmonary vascular resistance

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Background

Pulmonary arterial hypertension (PAH) is characterized by progressive increase in pulmonary vascular resistance (PVR), leading to right ventricular (RV) failure [1]. PVR is calculated using right heart catheterization (RHC), from the trans-pulmonary pressure gradient (ΔP) and pulmonary flow (Q_{PA}). Doppler echocardiography can estimate PVR from the ratio of peak tricuspid regurgitation velocity (TRV) to main pulmonary artery velocity time-integral (MPA flow) [2]. MRI is increasingly used to assess right ventricular (RV) function in PAH. Determining PVR from MRI could enable a more complete characterization of RV and PA interactions in PAH. The purpose of this study was to non-invasively estimate PVR from TRV/Q_{PA} using a 4D flow-sensitive MRI sequence in humans [3].
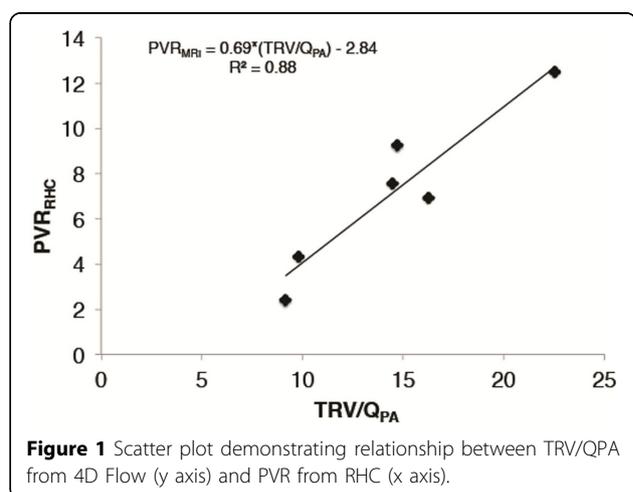
Methods

Six PAH patients referred for right heart catheterization (RHC) and six healthy volunteers were scanned according to an IRB-approved protocol. In patients, RHC was performed clinically within 1 week of the MRI in patients with PAH. PVR$_{RHC}$ was calculated as follows: PVR=ΔP/Q_{PA}. 4D flow MRI (Phase Contrast with Vastly undersampled Isotropic Projection Reconstruction - PC VIPR) was performed on 3T clinical scanners (GE Healthcare, Waukesha, WI) after the administration of gadolinium-based contrast agents. PC VIPR parameters: FOV=32 x 32 x 22 cm, isotropic 1.3 mm spatial resolution, TR/TE = 6.3/2.1 ms, Venc=150 cm/s, scan time: ~10 min using respiratory and retrospective ECG gating. Post-processing was done using Ensight (CEI, Apex, NC) and MatLab (The Mathworks, Natick, MA) to measure peak TRV and Q_{PA}. Statistical analysis included regression analysis to evaluate the correlation between TRV/Q_{PA} and PVR$_{RHC}$. A regression equation was derived to calculate PVR$_{MRI}$. Differences between PVR$_{MRI}$ and PVR$_{RHC}$ were assessed using Bland-Altman analysis. TRV/Q_{PA} ratios in healthy controls were compared to those in PAH patients using Student t-test.

Results

Average (± standard deviation) PVR$_{RHC}$ was 7.15 ± 3.56 UW. The Pearson correlation coefficient between TRV/Q_{PA} and PVR$_{RHC}$ was 0.94. The equation derived from linear regression was PVR$_{MRI}$ = 0.69*PVR$_{RHC}$ - 2.84 UW. Using this equation, the average (± standard deviation) PVR$_{MRI}$ was 7.15 ± 3.35 (p=0.99). The mean difference between PVR$_{MRI}$ and PVR$_{RHC}$ was 0 with positive and negative levels of agreement of 2.4 and -2.4, respectively. Differences in TRV/Q_{PA} in healthy controls and PAH patients were statistically significant (p=0.0003).

Figure 1 Scatter plot demonstrating relationship between TRV/Q_{PA} from 4D Flow (y axis) and PVR from RHC (x axis).

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Figure 2 TRV/QPA comparison between PAH patients and healthy controls. Differences are statistically significant (p=0.0003)
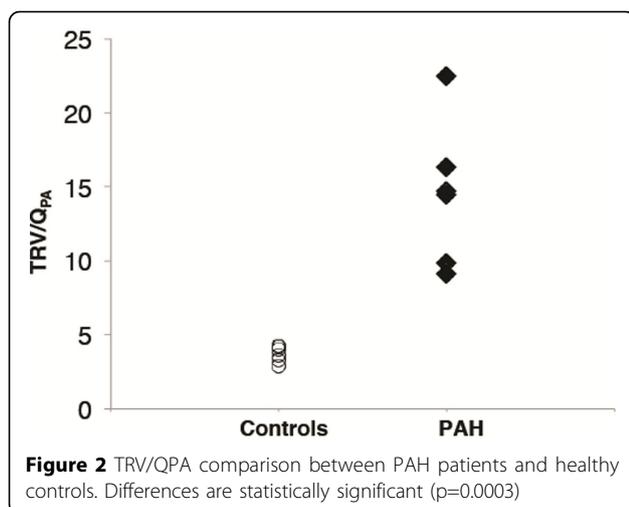
Conclusions

PVR can be accurately estimated noninvasively using 4D flow MRI. The results from this study indicate that 4D flow-sensitive MRI with PC VIPR can also be used to estimate PVR, complementing the analysis of alterations in flow patterns in the heart and pulmonary arteries in patients with cardiopulmonary disease. Data from a different cohort of patients will be used for validation.

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