4D flow assessment of pulmonary artery flow and wall shear stress in adult pulmonary hypertension: results from two institutions

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Target audience: Those with interest in cardiopulmonary physiology, pulmonary arterial hypertension, and 4D Flow MRI

Purpose: Pulmonary hypertension (PH) is associated with substantial morbidity and mortality [1]. The disease is characterized by a stiffening of the pulmonary arteries (PA) and an increase in pulmonary artery pressure (PAP). The aims of this two-center study were (1) to determine if PA flow and WSS can be reliably measured using two different four-dimensional flow-sensitive (4D Flow) MRI techniques (radial and Cartesian k-space sampling) and (2) to characterize differences in PA hemodynamics between healthy and PH subjects.

Methods: Healthy volunteers (n=19; 14M, 38.6±13.3y) and subjects with PH (n=17; 6M, 56.7±9.9y) were recruited at two sites according to an IRB-approved protocol. Presence and severity of PH was determined with right heart catheterization (mPAP=44.5±17.0mmHg, PVR=491±236dyn·s/cm⁵). At Site 1 (n=19; 10PH), 4D Flow MRI was performed with a Cartesian acquisition (Siemens scanners, TR/TE=4.8-6.6/2.3-3.4ms, FA=7-15°, FOV=340-400x200-300mm, VENC=150-400cm/s) [2]. At Site 2 (n=17; 7PH), 4D Flow MRI was performed with a three-dimensional radially undersampled acquisition (GE scanners, PC-VIPR, TR/TE=6.1-8.9/2.1-3.2ms, FA=10-14°, FOV=320x320x220mm, VENC=75-150cm/s) [3]. Two-dimensional cutplanes in the main pulmonary artery (MPA), right pulmonary artery (RPA), and left pulmonary artery (LPA) (Fig. 1) were generated interactively from the 4D Flow MRI datasets using Ensight (CEI, Apex, NC) and exported for quantitative analysis in homebuilt Matlab software (The Mathworks, Natick, MA) [2]. Two blinded, independent observers, one at each institution, analyzed all 4D Flow MRI datasets from both institutions. MPA, RPA, and LPA peak systolic velocity (PSV), peak flow (Qmax), total flow (Qnet), and regional WSS were recorded for each study. Statistical analysis included assessment of inter-observer variability, inter-site differences, and differences in hemodynamic parameters between healthy volunteers and subjects with PH.

Results and Discussion: Cartesian vs. radial: MPA, RPA, and LPA flow data are summarized in the Table. Differences between inter-site groups may be attributed to individual physiologic flow differences, since the same subjects were not examined at both sites. PH vs. healthy volunteers: All measured flow parameters were significantly lower (p<0.05) in PH subjects than in healthy volunteers (Table and Fig. 2).

Conclusions: 4D Flow MRI can be used to reliably assess differences in pulmonary artery hemodynamics in patients with PH. Flow and WSS measurements in healthy and PH volunteer cohorts were similar whether obtained using either Cartesian- or radial-based 4D Flow MRI acquisitions with minimal inter-observer variability.