Scan-rescan reproducibility of flow and pressure difference using 4D flow MRI in pulmonary artery

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Target audience: Researchers interested in 4D flow MRI, pressure difference mapping and pulmonary artery hypertension.

Purpose: 4D flow MRI has been widely used for the assessment of in vivo blood flow [1]. Blood flow and pressure difference (PD) are two important clinical markers for the severity discrimination of cardiovascular disease [2]. Previous work found high reproducibility of blood flow and WSS in aorta and pulmonary artery (PA), but the reliability of PD has not been studied [2,3]. Therefore, the aim of this study was to investigate the scan-rescan reproducibility of blood flow and PD using 4D flow MRI in PA.

Methods: *MRI Scan:* The PAs of four healthy volunteers (mean age 25 years) were scanned twice using 4D flow sequence in our study after approval by the local ethics committee and written informed consent. The second scan was repeated 20 mins later after the first scan. All measurements were performed on a 3T MRI scanner (Philips Achieva, TR/TE = 3/2ms, Flip Angle = 5 deg, FOV = 200-220 x 200-220 mm^2, VENC = 150cm/s, Temporal Resolution = 39-45ms). *Flow Analysis:* Flow quantification was performed using GTFlow 2.1.9 (Gyrotools, Zurich, Switzerland) in main pulmonary artery (MPA), right pulmonary artery (RPA) and left pulmonary artery (LPA) (Figure 1). *PD Analysis:* PA was segmented from PC-MRA data [4] using Mimics (MIMICS, Materialise Inc., Belgium). PD was calculated based on integration and iterative refinement of pressure gradients using the Navier-Stokes equation described previously using Matlab (The MathWorks, MA, USA) [5]. Visualization and mean PD measurements were implemented in Ensight (CEI, NC, USA). To compare the mean pressure difference between subjects, three 2D cross-sections were selected in MPA, RPA and LPA and reference points (pressure difference $\Delta P = 0$) were set manually within the main PA at the same level of the lower edge of aorta (Figure 2). This reference point was also used as a starting point for a 3D flood-filling algorithm to generate a 3D vessel mask containing only voxels from PA. *Statistical Analysis:* Scan-rescan reproducibility of peak flow, total flow, peak systolic PD and peak diastolic PD of MPA, RPA and LPA were evaluated using the Bland-Altman comparisons.

Results and Discussion: Continuous PD was presented as mean ± standard deviation in Figure 2. The small standard deviations for healthy subjects indicated small inter-subject difference. The mean difference of peak flow and total flow between two scans were 0.004 L/s and 0.001 L/cycle respectively, and the mean difference of peak PD between two scans was -0.007 mmHg (Figure 3), which demonstrated high scan-rescan reproducibility.

Conclusion: Blood flow and PD measured in PA using 4D flow MRI can achieve good scan-rescan reproducibility.

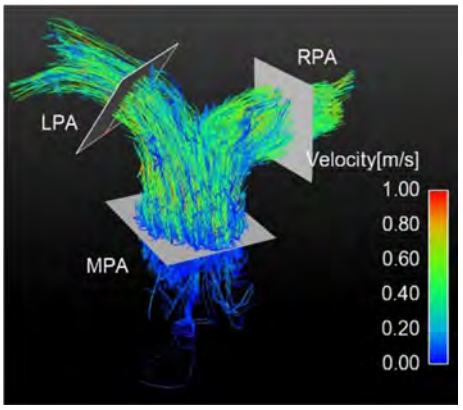

Figure 2. Particle traces of pulmonary artery and location of plane.

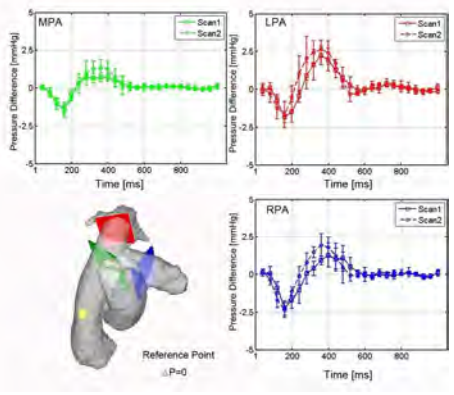

Figure 2 . Mean pressure differences in three analysis planes averaged over 4 volunteers. Error bars reflect inter-individual standard deviations of flow among subjects.

Reference: [1] Michael Markl, et al. Jouranl of Magnetic Resonance Imaging 2012;1015:1036 [2] Alex J.Barker, et al. Magnetic Resonance in Medicine 2014; 00:00. [3] Michael Markl, et al. Jouranl of Magnetic Resonance Imaging 2011;988:994 [4] Bock J, et al. Magnetic Resonance in Medicine 2010;330:338. [5] Jelena Bock, et al. Magnetic Resonance in Medicine 2011;1078:1088.

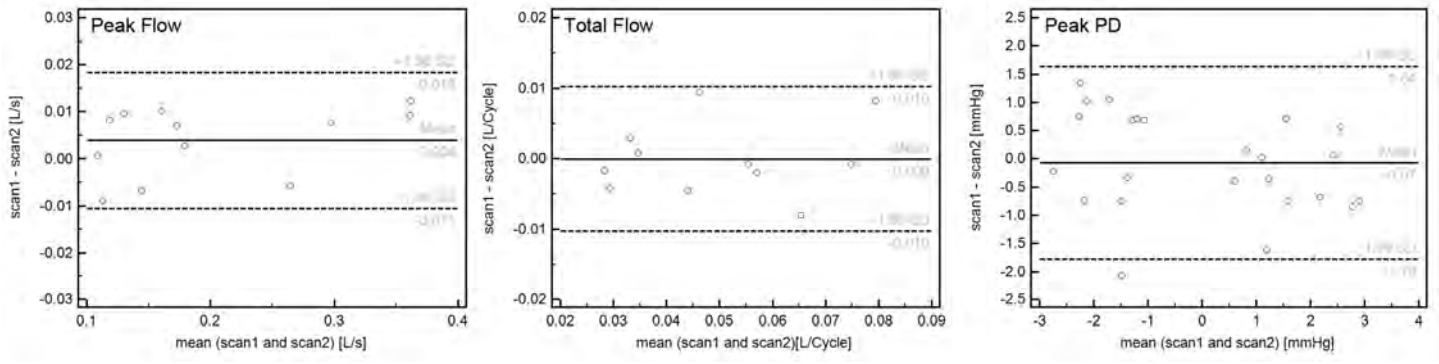

Figure 3. Bland and Altman analysis of reproducibility (scan-rescan variability) for flow and peak pressure difference calculation in the pulmonary artery.