Noninvasive 4D Blood Flow and Pressure Quantification in Central Blood Vessels via PCMRI

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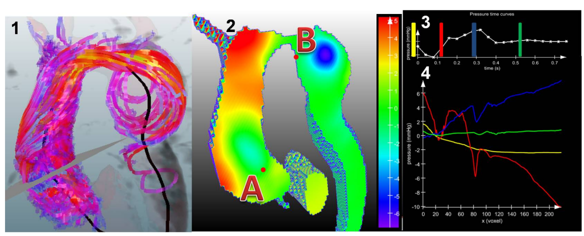
Introduction. Local vessel anatomy and haemodynamics is a key factor for diagnosis and therapy planning in patients with aortic aneurysma and congenital heart diseases. Recent progress in MRI technology has facilitated time- and spatially resolved (4D) PCMRI velocity-encoded measurements in reasonable scan times. Purpose of this work is the demonstration of new methods for noninvasive assessment of detailed haemodynamical parameters in central blood vessels based on advanced postprocessing methods.

Methods. The semi-automatic image processing chain of the 4D PC data consists of an eddy current correction and phase unwrapping , followed by PC-MRA calculation in order to extract the vessel lumen. The pressure calculation is done by solving the Pressure-Poisson equation with Neumann boundary conditions via the finite-element method directly in the segmented flow volume. The algorithm was validated by comparison with Lattice-Boltzmann flow simulations of a turbulent flow jet in a stenotic vessel phantom and tested on 4D PCMRI measurements from a 3T system covering the entire thoracic aorta (spatial resolution $1.8\times1.8\times\ 2.6\,\mathrm{mm}^3$, temporal resolution 40 ms, venc 150 cm/s).

Results. The CFD validation showed that the pressure drop along a stenosis can be well predicted by our algorithm. A first evaluation of the method on in-vivo data of patients with aortic aneurysma as well as patients that underwent Fontan procedure was successfully performed.



1,2) Flow pathlines and pressure in aortic aneurysma at late systole. 3) Pressure difference between A and B over the cardiac cycle. 4) Pressure along centerline (black line in (1)) at different times.

Conclusions. The proposed noninvasive methods yield valuable information on local haemodynamic parameters and can improve diagnosis and therapy planning.