Enhancing Imaging in Medical Engineering using HPC: Application to an Aortic Phantom

J. Kratzke[1] and V. Heuveline[2]

Abstract: Anatomical aspects of aortic disease have been thoroughly investigated in the last decades by means of CT, MRI and ultrasound. To date, morphologic variations can be determined individually and with high sensitivity. However, with respect to the coherence between biomechanical behavior and aortic disease, various open questions exist, such as for a more extensive acquisition of risk factors for atherosclerosis, aneurysm formation or aortic dissection.

Within the scope of increasing understanding of vascular pathology, development of functional imaging of the aorta becomes more and more important. An innovative method to investigate the biomechanical behavior of blood vessels is given by aortic silicon phantoms and 4D phase contrast (PC)-MRI measurement. Entirely made of non-metallic components, blood-like fluids can be flown through aortic phantoms and the time-resolved velocity field can be measured by PC-MRI technology.

In this work we propose a mathematical model of an aortic silicon phantom and a framework that allows to enhance 4D PC-MRI imaging by means of combining numerical simulation with MRI data. As the elasticity of the silicon phantom wall plays a significant role and is reflected in the Windkessel effect in the case of the aortic bow, we model the wall as elastic structure. The resulting fluid-structure interaction problem is solved numerically in a monolithic finite element based approach using the HiFlow software framework.

The proposed setup is calibrated by means of 4D PC-MRI imaging of the considered silicon phantom. It is evaluated by comparing experimental and numerical data in the framework of the aortic phantom. In addition to the measured velocity field it provides information about wall shear stress and stress distribution in the phantom's wall.

[1,2] Engineering Mathematics and Computing Lab (EMCL)
Interdisciplinary Center for Scientific Computing (IWR), Heidelberg University
Speyerer Str. 6, 69115 Heidelberg, Germany
jonas.kratzke@iwr.uni-heidelberg.de, vincent.heuveline@iwr.uni-heidelberg.de