High-Resolution Time-Resolved 3D Quantitative Flow MRI of Intracranial Vessels

M. Piccirelli[1], G. R. Crelier[2], R. Luechinger[1], S. Kozerke[1], and P. Boesiger[1]

[1]Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland, [2]Gyrotools GmbH, Zurich, Switzerland

Introduction

Time-resolved three-dimensional PC-MRI allows in-vivo acquisition of four-dimensional hemodynamic data in large vessels. In the aortic arch the depiction of velocity vectors, flow-field stream lines, and particle path lines reconstructions has been proven beneficial for the understanding of flow patterns and structure over the cardiac cycle, especially in the presence of congenital or acquired abnormalities[1]. There is considerable interest in expanding the application of these techniques to the intracranial arteries, as several cerebrovascular diseases are interlinked with abnormal flow[2]. However, the relative small scale of the arterial structures of interest requires acquisition of velocity information with high spatial resolution. The objective of this work was to investigate the feasibility of high resolution 3D quantitative flow MRI of intracranial vessels.

Methods

High resolution time-resolved 3D PC MRI protocols were optimized on 3 healthy volunteers on a 3T system (Philips Healthcare, Best, Netherlands) with 8-channel head coil. The nominal spatial resolution was varied from 0.5 to 0.15mm^3 voxel volume. The other imaging parameters were: TE/TR 3.6-5.9/6.9-9.7ms, FOV 22x18x2.2cm, Venc 90cm/s, 19 cardiac phases, scan duration 17-37min, retrospective VCG triggering, SENSE factor 1.5-3.0.

Visualization of flow velocities, region-of-interest (ROI) analysis, and particle path lines reconstructions were performed with a commercial software package (GyroTools, Zurich, Switzerland). To measure and compare velocity profiles, cross-sectional planes were placed perpendicular to flow through the basilar artery (BA), through the left and right posterior cerebral arteries (LPCA , RPCA), inside the cavernous segments of the left and right internal carotid arteries (LICA, RICA), and after the ICA bifurcation in the anterior cerebral arteries (LACA, RACA). ROIs encompassing the vessel lumen were drawn in these planes for all phases of the cardiac cycle and used for quantification.

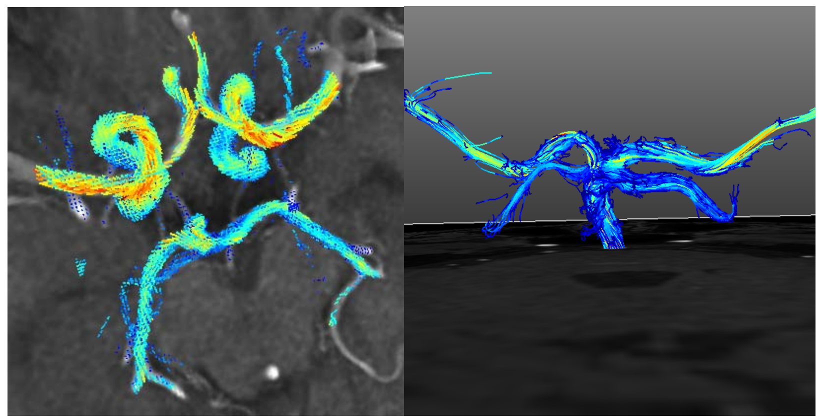

Figure 1: Velocity vector display in the Circle of Willis (left), particle path line reconstruction in the basilar artery (right).

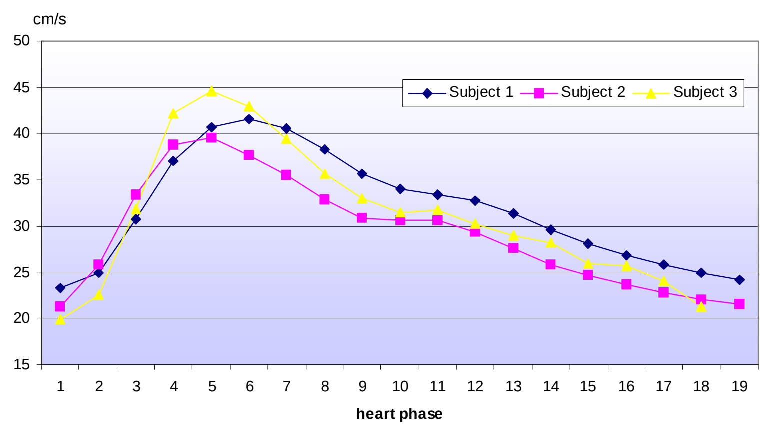

Figure 2: Mean flow velocities over heart cycle in the basilar artery.

Results

Flow velocities could be quantified in all volunteers and at all resolutions. Results with the 0.3mm^3 voxel size protocol are summarized in Figures 1,2 and Table 1. At resolutions below 0.3mm^3 erroneous path lines reconstructions in the smaller vessels were an indication of insufficient SNR. At 0.3mm^3 voxel size, very small arteries such as the posterior communicating arteries were clearly visible. Peak flow velocities of up to 6.8cm/s could be measured in these arteries.

Discussion and Conclusion

Quantitative flow data of sufficient spatial resolution is required for resolving flow patterns in very small structures like the communicating arteries or small-sized aneurysms. Our results indicate that time-resolved 3D quantitative flow measurements of the intracranial arteries is feasible on a clinical system with a spatial resolution of down to 0.3mm^3 voxel size. Wall shear stress determination feasibility need to be investigated.

	Maximum Velocity (cm/s)	Peak Mean Velocity (cm/s)	Peak Flow (ml/s)
BA	67.4 / 64.2 / 65.2	44.6 / 39.6 / 41.6	4.8 / 3.6 / 4.2
LPCA	69.7 / 45.9 / 66.3	43.3 / 32.7 / 44.8	1.6 / 1.2 / 1.7
RPCA	66.9 / 45.3 / 51.7	44.8 / 29.8 / 36.7	1.5 / 1.2 / 1.5
LICA	80.6 / 71.1 / 62.8	41.2 / 47.9 / 45.3	4.4 /4.1 / 5.1
RICA	93.1 / 59.0 / 70.2	38.3 / 40.5 / 50.4	5.8 / 4.1 / 5.1
LACA	101.1 / 77.4 / 77.9	51.3 / 51 .8 / 54.4	2.6 / 2.8 / 3.4
RACA	90.4 / 73.8 / 70.5	44.7 / 42.4 / 57.4	4.1 / 3.1 / 1.9

Table 1: Measured flow values in the major arteries of the Circle of Willis.

References:

[1] Markl, Michael et al, Time-Resolved 3-Dimensional Velocity Mapping in the Thoracic Aorta: Visualization of 3-Directional Blood Flow Patterns in Healthy Volunteers and Patients, J Comput Assist Tomogr. 28(4):459-68, 2004

[2] Bammer, Roland et al, Time-Resolved 3D Quantitative Flow MRI of the Major Intracranial Vessels: Initial Experience and Comparative Evaluation at 1.5T and 3.0T in Combination With Parallel Imaging, MRM 57:127–140, 2007