Analysis of Aortic Hemodynamics after Treatment for Coarctation Using Flow-Sensitive 4D MRI at 3T

A. Frydrychowicz1, D. Hirtler2, R. Arnold3, A. Berger1, A. F. Stalder1, J. Bock3, A. Harloff1, M. Langer1, J. Hennig1, and M. Markl1

1Diagnostic Radiology, Medical Physics, University Hospital Freiburg, Freiburg, Germany; 2Pediatric Cardiology, University Hospital Freiburg, Freiburg, Germany; 3Neurology, University Hospital Freiburg, Freiburg, Germany

Introduction: Aneurysm formation or re-stenosis constitute life-threatening secondary complications after therapy in aortic coarctation which may occur years and decades after initial surgery [1]. The identification of patients at risk for the development of such pathologies is of high interest and requires a detailed understanding of the link between vascular malformation and altered hemodynamics. Since flow-sensitive, time-resolved 3D examinations (flow-sensitive 4D MRI) have become available and enable for a large volumetric coverage [2], alterations in aortic flow patterns can be detected further upstream and downstream of the aorta. Analysis is not restricted to the pathology as in single-slice 2D acquisitions. Initial results from coarctation and aneurysm formation have recently been reported as case reports [3]. It was the aim of this study to evaluate the hemodynamic alterations in aortic blood flow before (n=2) and after (n=22) coarctation repair by flow-sensitive 4D MRI at 3T in a larger collective of 24 patients and to compare findings to results in 25 volunteers with normal aortic geometry (aortic diameter aorta ≤ 30mm).

Methods: 24 patients (16m, 8f; age 16.8±7.3years; 56.6±18.6kg BW) were included in the study. Flow-sensitive 4D MRI was performed in 22 patients 11.6±4.7years after coarctation repair (12 resection end-to-end and end-to-side, 5 Waldhausen-, 2 VossSchulte-procedures, 3 angioplasties). The remaining 2 patients did not yet receive therapy. Experiments were performed on a 3T MR-system (TRIO, Siemens, Germany) after written informed consent. For comparison, data from 25 normotensive volunteers (14m, 11f, age 38.6±16.9years, 70.1±10.8kg BW) without geometrical alterations of the aorta from a previous study were included as a reference [4]. Data acquisitions covered aortic blood flow before (n=2) and after (n=22) coarctation repair by flow-sensitive 4D MRI at 3T in a larger collective of 24 patients and to compare findings to results in 25 volunteers with normal aortic geometry (aortic diameter aorta ≤ 30mm).

Results: 3D-PC-MRA in connection with 3D flow visualization in the aortic arch. Vortical flow patterns at the branching site of the left subclavian artery (white arrows) were observed in 15/24 patients. This finding could be observed irrespective of the treatment. The patient also showed typical flow acceleration over a mild re-stenosis (lower white arrow).

Discussion: The results provide insights into the nature of aortic hemodynamics before and after different repair strategies for aortic coarctation. Particularly flow changes not directly associated with the site of the stenosis such as enhanced flow velocities and vortices in the subclavian artery were unexpected. These findings underline the complexity of the hemodynamic consequences of the disease. Although the cohort is heterogeneous, there are signs of common impaired flow patterns that may facilitate secondary complications such as aneurysm formation. The development of vortices at the site of the branching of the left subclavian artery observed in large number of patients may result in reduced shear forces at this site which are known to promote endothelial remodeling and thus may facilitate aneurysm formation. Indeed, the observed cohort of patients included patients representing different stages of such aneurysm growths with early onset of dilatation as in figure 1 and 3A and potentially flow mediated larger aneurismal structures as in figure 3B. Although a multifactorial etiology of secondary alterations is likely, our findings offer a first hint towards the significance of in-vivo evaluation of blood flow for the diagnosis or follow-up of the development of aortic pathology.

Acknowledgements: Deutsche Forschungsgemeinschaft (DFG), Grant # MA 2383/4-1, Bundesministerium für Bildung und Forschung (BMBF), Grant #01EV0706