

## Aorto-iliac flow sensitive MRI: Blood Flow pre and post endovascular aortic repair

Maximilian Frederik Russe<sup>1</sup>, Philipp Blanke<sup>1</sup>, Wulf Euringer<sup>1</sup>, Julia Geiger<sup>1</sup>, Zoran Stankovic<sup>1</sup>, Bernd Jung<sup>1</sup>, and Mathias Langer<sup>1</sup>

<sup>1</sup>Diagnostic Radiology - Medical Physics, University Hospital, Freiburg, Germany

**Introduction:** Compared to the healthy aorta, aortic aneurysms show blood flow changes in the aneurysms and the adjacent vascular segments with altered forces at the vessel wall, constituting potential new risk factors for aneurysm progression, thrombus formation or rupture [1, 2]. Endovascular aortic repair (EVAR) with stent grafts is an accepted treatment option with outcome similar to open repair [3]. However, EVAR-specific complications such as iliac limb thrombosis, functional stenosis or proximal neck dilation with the risk of stent migration occur and may be related to altered blood flow patterns proximal to and throughout the stent graft [4]. Blood flow patterns in aneurysms can be studied using flow sensitive MRI. The purpose of this study was to assess the feasibility of flow sensitive MRI after EVAR and to investigate alterations in blood flow pattern and flow characteristics throughout the stent graft post EVAR induced by the stent graft itself.

**Methods:** In 8 male patients (age  $72 \pm 7$  years) with infrarenal aortic aneurysm flow-sensitive 4D MRI based on an RF-spoiled gradient-echo sequence with interleaved three-directional velocity encoding was performed on a 3T scanner prior and after EVAR (Anaconda™ AAA Stent Graft System, Vascutec Terumo, Japan). Data acquisition was prospectively ECG-gated during free breathing using navigator respiratory gating based on diaphragm motion [5]. Imaging parameters were:  $v_{enc} = 80\text{cm/s}$ - $120\text{cm/s}$ , spatial res.  $= 1.01\text{-}1.17 \times 2.2\text{-}2.8 \times 2.32\text{-}2.73\text{mm}^3$ , flip angle  $= 10^\circ$ ,  $TE = 2.5\text{-}2.7\text{ms}$ ,  $TR = 5.2\text{-}6.1\text{ms}$ , temporal res.  $= 40\text{-}41, 6.8\text{ms}$ , coronal-oblique 3D Volume. Data processing included eddy current and velocity aliasing correction. Flow pattern analysis (EnSight, CEI, Apex, USA) was performed using particle traces and flow quantification [6] with analysis planes at the following vascular locations: pre-renal, post-renal, aneurysm/stent (main body), iliac arteries/limbs (AIC) [Fig. 1].

**Results:** Flow-sensitive 4D MRI and blood flow visualization and quantification was successfully performed in all patients. Pre EVAR aortic blood flow patterns were characterized by vortex-formation and flow deceleration during passage through the aneurysm, regaining flow velocity in the proximal iliac arteries [Fig. 2, 4]. Post EVAR, blood flow was laminar without vortex formation in the stents' main bodies and iliac limbs. Post EVAR, average flow velocity within the stents' main bodies was similar to average flow velocity proximal to the stent graft (post-renal) [Table 1, 2, Fig. 4]. Average flow velocity in the iliac limbs was strongly increased, gaining 58-

75% compared to pre-EVAR velocities [Table 2]. Focal, pronounced blood-flow accelerations ( $>90\text{cm/s}$ ) were observed in 2 patients in one iliac limb [Fig. 3].

**Discussion:** Flow-sensitive 4D MRI allows for comprehensive aorto-iliac MR flow analysis prior and after EVAR. This technique has the potential to gain insights into relationship between anatomy, stent design and deployment and post-EVAR complications, possibly related to blood flow alterations induced by the stent graft itself.

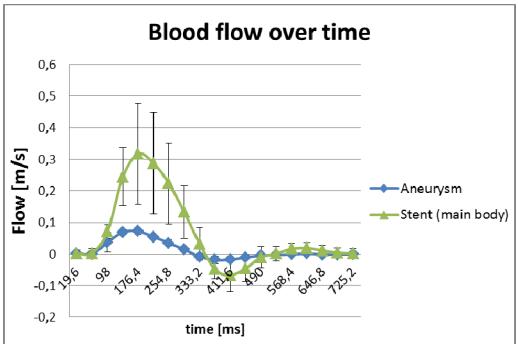


Figure 4: Blood flow [m/s] over time [ms] in infrarenal aneurysm vs. stent (main body)

Table 1: Total flow volume per heart cycle [mL/cycle]

Total flow per cycle [mL/cycle]	prerenal	postrenal	Aneurysm/Stent (main body)	left AIC	right AIC
before EVAR	$24.16 \pm 6.1$	$15.14 \pm 2.29$	$14.35 \pm 0.82$	$6.14 \pm 1.84$	$5.32 \pm 1.25$
after EVAR	$25.37 \pm 13.49$	$10.12 \pm 3.73$	$12.51 \pm 3.79$	$3.91 \pm 1.24$	$5.02 \pm 1.92$
% after vs. before EVAR	4.99	-33.13	-12.81	-36.35	-5.6

Table 2: Mean flow [cm/s] over the whole heart cycle

meanflow [cm/s]	prerenal	postrenal	Aneurysm/Stent (main body)	left AIC	right AIC
before EVAR	$10.13 \pm 4.48$	$7 \pm 2.49$	$1.34 \pm 0.29$	$5.35 \pm 1.62$	$5.73 \pm 3.01$
after EVAR	$9.5 \pm 4.32$	$6.17 \pm 2.74$	$6.32 \pm 2.85$	$8.46 \pm 3.01$	$10.04 \pm 5.51$
% before vs. after EVAR	-6.22	-11.85	373.12	58.08	75.27

### References:

1. Frydrychowicz A et al. J Cardiovasc Magn Reson 2008; 10(1), 2.
2. Hope TA et al. J Magn Reson Imaging 2007; 26(6); 3.
3. United Kingdom EVAR Trial Investigators, N Engl J Med. 2010; 362(20); 4.
4. Maleux G et al. J Vasc Interv Radiol. 2008; 19(10)
5. Markl M, et al. J Magn Reson Imaging 2007;25(6):1250-1256.
6. Stalder AF Magn Reson Med. 2008;60(5).

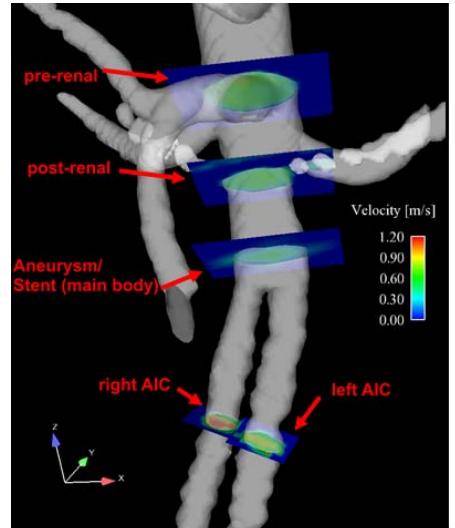


Figure 1: Positions of analysis plane

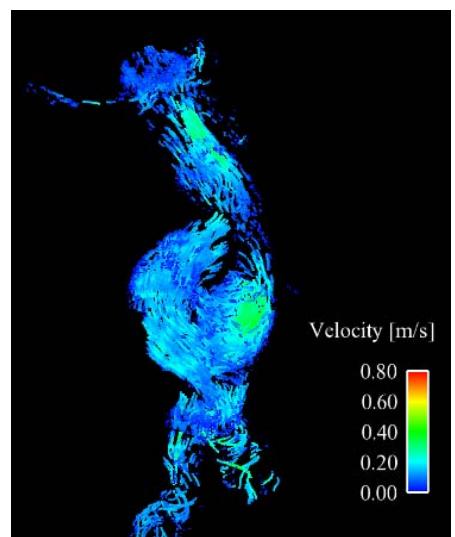


Figure 2: Vortex-formation in infrarenal aneurysm

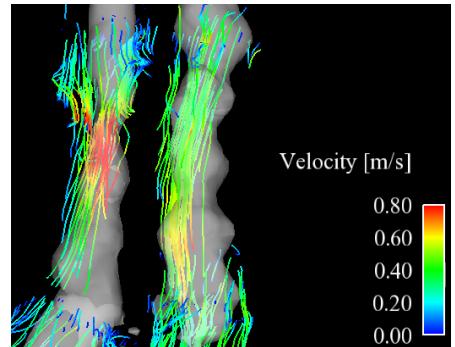


Figure 3: Blood flow acceleration in the right iliac limb