**Comparing steady and pulsatile LDV and PC-MRA flow measurements in an anatomically accurate cerebral artery aneurysm model**

D. I. Hollnagel[1], P. E. Summers[2], S. S. Kollias[3], D. Poulikakos[1]

[1]Laboratory of Thermodynamics in Emerging Technologies, ETH Zurich, Zurich, Switzerland, [2]Nuffield Department of Surgery, University of Oxford, Oxford, United Kingdom, [3]Institute of Neuroradiology, University Hospital, Zurich, Switzerland

## BACKGROUND:

Blood flow measurements in cerebral aneurysms are gaining in importance for clinical and research purposes. A non-invasive method for performing in vivo blood flow measurements is Phase-Contrast Magnetic Resonance Angiography (PC-MRA). To verify the accuracy of the PC-MRA even in small artery systems, we surveyed an original geometry cerebral aneurysm model by the state-of-the-art Laser Doppler Velocimetry (LDV) and PC-MRA measurements.

## METHODS:

***Model and set up:*** We segmented the aneurysm geometry from a patient's Digital Subtraction Angiography. From the processed file, Elastrat, Geneva, manufactured a clear silicone model (Fig. 1).

We used a blood mimicking fluid of 59.4 % glycerol in water with the same refraction index as the model. Hollow glass spheres were added as seeding particles for the LDV. During the MRA the model was covered with agar gel to improve the MR signal. We adjusted the flow to in vivo blood properties due to Reynolds and Womersley analogies. To assure a reproducible flow, we chose a computer controlled pump from Shelley Medical Systems, CompuFlow 1000MR [1].

***Flow measurements:*** We performed flow measurements in a Dantec 2-D LDV set up and in a 3 T Philips Gyroscan MR scanner. A constant flow rate of 5.4 ml/s and a pulsatile flow curve with a frequency of 2 Hz, similar to an *in-vivo* blood flow curve, were applied. For the LDV, we used two Argon-Ion Lasers with different wavelengths so that velocities in two directions could be measured. For the PC-MRA, we used standard 2-D and 3-D sequences which allowed the acquisition of velocity data in three directions.

## RESULTS AND DISCUSSION:

The constant axial velocity profiles at the inlet measured with LDV and PC-MRA are shown in Figs. 2 and 3. The LDV results show a smooth velocity profile in a high resolution of approximately 0.1 mm. Besides small MR artifacts, the PC-MRA results clearly show a similar profile, but with a lower spatial resolution of 0.45 mm. The dimension of the arterial cross-section is represented precisely.

LDV and PC-MRA velocity profiles through the maximum velocity point are shown in Figs. 4 and 5 and indicate a close match. The peak velocitiy difference is approx. 11 %.

The pulsatile results at the horizontal outlet show that the flow cycles measured with LDV and PC-MRA produce similar results (Fig. 6). The high velocity profiles match well whereas low velocities are undervalued by the PC-MRA. In contrast, the cross-section of the artery is overvalued by the PC-MRA. A reason for that might be the slice thickness of the MRA. Because of changes in the artery geometry along the slice thickness, the area of the flow region appears larger than it actually is.

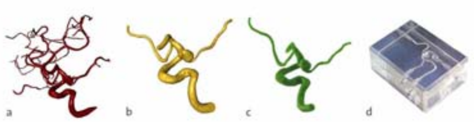


Figure 1: Process line of the model: (a) angiography data, (b) cropped data, (c) 3-D wax model, (d) silicone model.

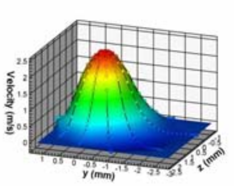

Figure 2: LDA results at the inlet for constant flow in axial direction.

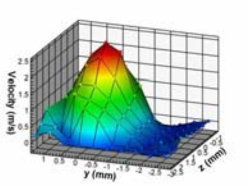

Figure 3: 3-D PC-MRA results at the inlet for constant flow in axial direction.

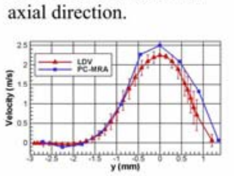


Figure 4: Cut in y-direction through max. velocity at the inlet for constant axial flow.

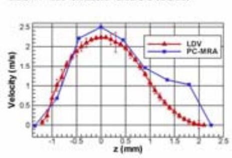


Figure 5: Cut in z-direction through max. velocity at the inlet for constant axial flow.

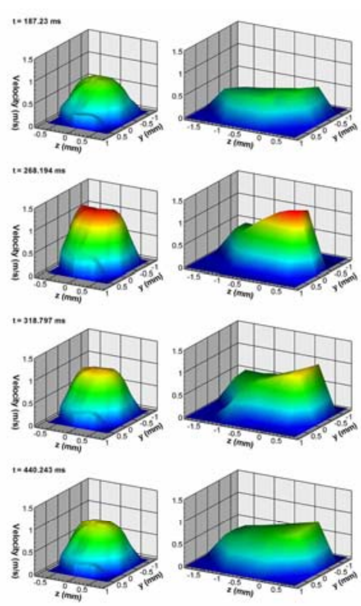

Figure 6: LDV (left) and 2-D PC-MRA (right) results at the model outlet for pulsatile axial flow at specific time steps.

## CONCLUSIONS:

We compared LDV to PC-MRA to obtain a precise estimate of the accuracy of PC-MRA in small artery systems. We presented that the flow profiles show strong similarities, even though the PC-MRA resolution is rather low and causes artifacts in very small arteries. As we assume improvements on the results by high-resolution scans, the next steps will point in that direction. A disadvantage of the high-resolution scans will be a longer scan time. With the proof of high accuracy even in small arteries and aneurysms, PC-MRA can be used to acquire patient data easily and non-invasively for clinical and further research purposes.

## REFERENCES:

[1] D.W. Holdsworth et al. (1991) Med Biol Eng Comp 29, 565-70

[2] S. Tateshima et al. (2004) J Neurosurg 100, 1041-8