

**MODERATED POSTER PRESENTATION**

**Open Access**

# 4D flow MRI of the aorta becomes practical: performance and observer variability for a new semi-automated workflow for 3D visualization and quantification of aortic hemodynamics

Susanne Schnell<sup>1\*</sup>, Pegah Entezari<sup>1</sup>, Riti J Mahadevia<sup>1</sup>, Daniel Rinewalt<sup>2</sup>, Jacob Fluckiger<sup>1</sup>, Jeremy Collins<sup>1</sup>, James Carr<sup>1</sup>, Bernd A Jung<sup>3</sup>, Michael Markl<sup>1,4</sup>

From 16th Annual SCMR Scientific Sessions  
San Francisco, CA, USA. 31 January - 3 February 2013

## Background

To systematically investigate the performance and inter-observer variability of a new standardized workflow for the analysis of aortic hemodynamics based on 4D-flow MRI in a study with 30 subjects. The semi-automated workflow was developed to ensure faster and standardized data analysis including systematic placement of analysis planes, 3D-flow visualization, and quantification of standard clinical flow parameters.

## Methods

ECG and respiration-synchronized flow-sensitive 4D MRI data (spatio-temporal resolution=2.1-2.9x2.1-2.5x2.5-3.2mm<sup>3</sup> / 37.6-40ms) were acquired in 10 healthy volunteers, 10 patients with dilation of the ascending aorta and 10 patients with bicuspid valves (BAV). After correction for noise, eddy-currents and aliasing (Bock et al, ISMRM 2007), the data were loaded into a 3D visualization software (Enlighten, CEI, USA). A set of macros was developed (in python) to minimize user interaction, permit a reproducible definition of analysis planes, and reduce time needed for comprehensive 4D-flow analysis. This included 1) automated calculation of 3D PC-MRA; 2) creation of 9 standardized analysis planes to be positioned manually along the aorta; 3) quantification of net, forward and reverse flow, regurgi-

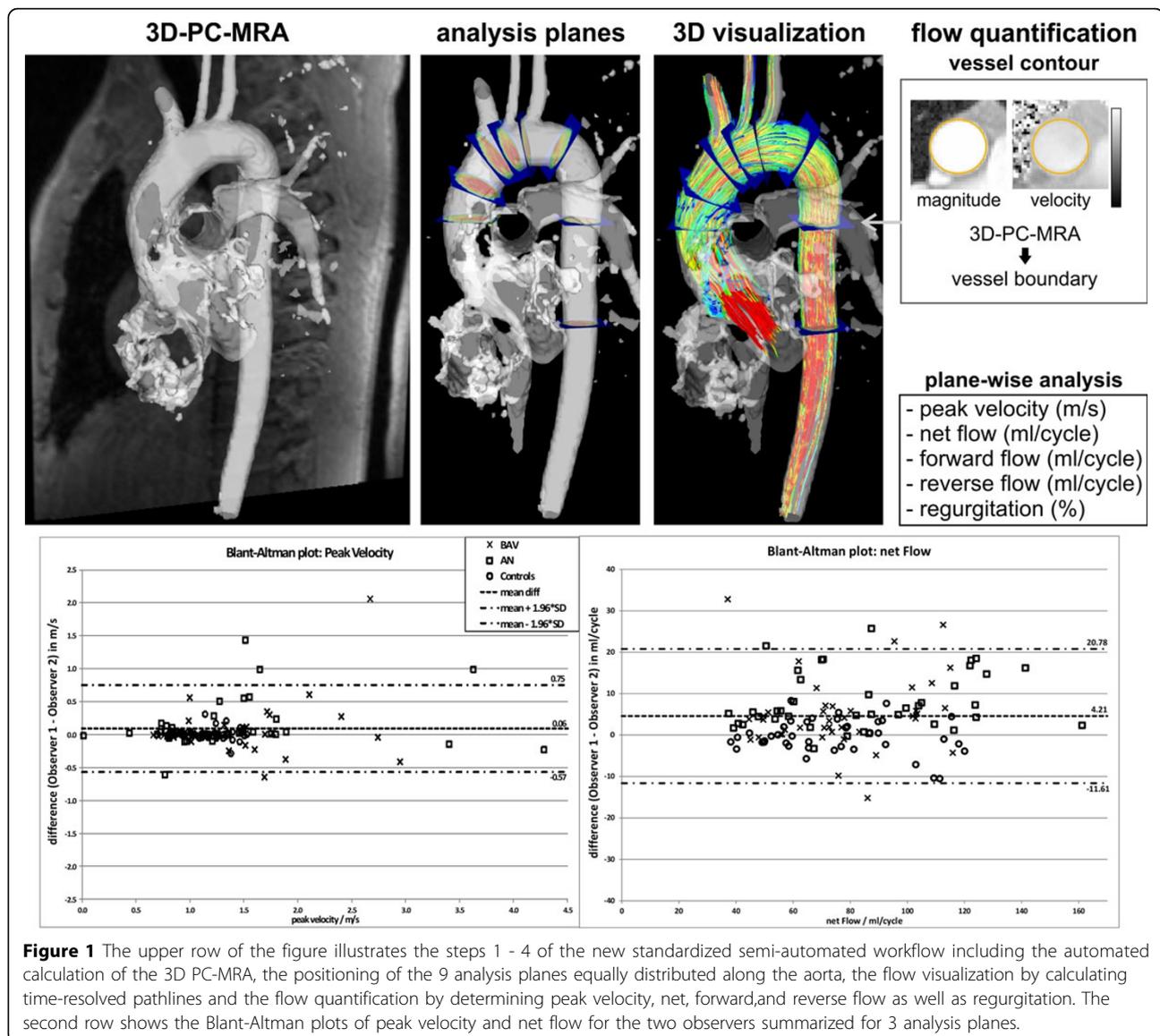
tation and peak systolic velocity; 4) 3D-flow visualization by time-resolved pathlines; 5) saving and export as images and movies (for presentation purposes and transfer to the hospitals PACS system). Steps 3-5 were fully automated. For evaluation, the data was analyzed by two independent observers, and agreement was tested in 3 analysis planes (mid-ascending aorta, mid-arch and proximal descending aorta).

## Results

In all 30 subjects the analysis was successfully completed and provided comprehensive information on aortic hemodynamics including planar flow quantification, and 3D-flow visualization with a 3D viewer (Enlighten, CEI, USA) as well as in standardized views as standalone videos and images. As summarized in figure 1 and table 1, inter-observer agreement was excellent for peak velocity, reverse flow and regurgitation (mean differences 4.59, 0.94 and 3.36% of the average parameters). The net and forward flow demonstrated moderate agreement (mean differences 5.4 and 5.1%). The mean analysis time for the complete analysis was 80min ±28. Note that the time was prolonged by the processing time needed generate the image and video files. For steps 1-4 only the analysis time was substantially reduced to 37.2min ± 12.5. The average time for noise, eddy currents and aliasing correction was 13.4min ± 5.8.

<sup>1</sup>Dept. of Radiology, Northwestern University, Feinberg Medical School, Chicago, IL, USA

Full list of author information is available at the end of the article



**Table 1 Quantification results showing the mean values, mean difference between the two observers and its limits of agreement (LOA)**

	Mean Controls	Mean BAVs	Mean Aneurysms	Mean Total	Mean Difference Controls	Mean Difference BAVs	Mean Difference Aneurysms	Mean Difference Total	LOA (+/-1.96*SD)
Peak Velocity (m/s)	1.16	1.31	1.22	1.32	0.02	0.10	0.16	0.09	0.66
Net flow (ml/cycle)	69.87	71.13	74.53	77.45	-0.86	6.40	8.22	4.59	16.19
Forward flow (ml/cycle)	70.53	73.73	77.16	79.40	-1.21	6.13	8.31	4.41	16.00
Reverse flow (ml/cycle)	-0.85	-2.48	-2.72	-2.00	-0.01	0.03	-0.26	-0.11	-3.11
Regurgitation (%)	1.23	3.54	3.93	2.71	0.05	0.32	0.15	-0.04	3.56

## Conclusions

Standardized 4D-flow MRI data analysis based on a macro oriented workflow can be performed with good inter-observer agreement and provides comprehensive information of aortic hemodynamics. Improved computation speed and better algorithms for the calculation of 3D visualization are needed to further reduce analysis time to clinically acceptable times.

## Funding

DFG (German Research Foundation) SCHN 1170/2-1.

## Author details

<sup>1</sup>Dept. of Radiology, Northwestern University, Feinberg Medical School, Chicago, IL, USA. <sup>2</sup>Cardiac Surgery, Rush University, Chicago, IL, USA. <sup>3</sup>Radiology, Medical Physics, University Medical Center Freiburg, Freiburg, Germany. <sup>4</sup>Biomedical Engineering, Northwestern University, Evanston, IL, USA.

Published: 30 January 2013

doi:10.1186/1532-429X-15-S1-M2

**Cite this article as:** Schnell *et al.*: 4D flow MRI of the aorta becomes practical: performance and observer variability for a new semi-automated workflow for 3D visualization and quantification of aortic hemodynamics. *Journal of Cardiovascular Magnetic Resonance* 2013 **15** (Suppl 1):M2.

**Submit your next manuscript to BioMed Central  
and take full advantage of:**

- Convenient online submission
- Thorough peer review
- No space constraints or color figure charges
- Immediate publication on acceptance
- Inclusion in PubMed, CAS, Scopus and Google Scholar
- Research which is freely available for redistribution

Submit your manuscript at  
[www.biomedcentral.com/submit](http://www.biomedcentral.com/submit)

