Visualization and quantification of increased tangential velocities in ascending aortic aneurysms using 4D phase contrast

B. R. Landgraf[1], K. M. Johnson[2], E. T. Bieging[1], O. Wieben[2], and C. J. François[1]
[1]Radiology, University of Wisconsin - Madison, Madison, WI, United States, [2]Medical Physics, University of Wisconsin - Madison, Madison, WI, United States

Introduction: Ascending aortic aneurysms (AscAA) are a life-threatening condition that could possibly lead to further dilation, aortic rupture and/or acute aortic dissection. Alterations in the flow conditions have been observed in AscAA and are thought to be associated with the pathophysiology of AscAA, as increased helical and vortical flow present greater tangential forces in the ascending aorta [1,2]. An understanding of the altered hemodynamic forces present in these patients could reveal important biomarkers for predicting adverse events. The purpose of this study was to compare the flow characteristics of patients with AscAA to those of normal volunteers using PC VIPR (Vastly undersampled Isotropic Projection Reconstruction) [3,4], an isotropic, high spatial resolution 4D phase contrast technique.

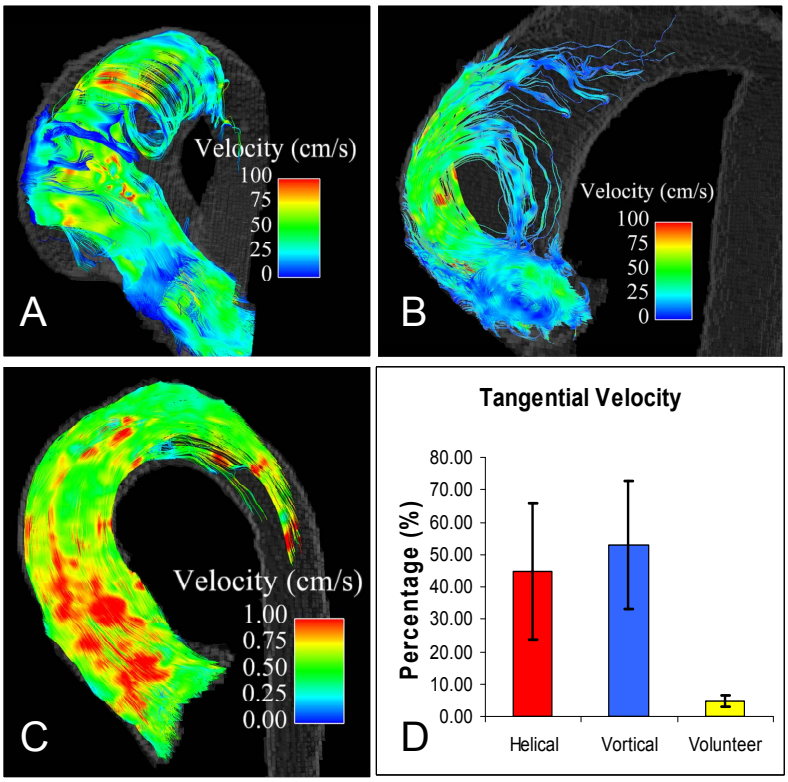

Figure 1 – Views of left aspect of aortic arch with streamlines to visualize flow. Helical (**A**) and vortical (**B**) flow patterns seen in AscAA patients; non-rotational laminar flow (**C**) in a volunteer. (**D**) Percentage of velocity tangential to direction of flow at peak systole is much higher in patients with AscAA than in normals.

Table 1 – MRI comparison between normal volunteers and patients with ascending aortic aneurysm

	Laminar	Helical	Vortical
Normal volunteers	11	0	0
Patients	0	9	4
Peak |v| (cm/s)	119.9 +/- 33.0	78.0 +/- 29.1	124.5 +/-113.7 *
Mean |v| (cm/s)	52.7 +/- 12.3	25.3 +/- 12.6	37.3 +/- 33.9
Tangential %	4.76 +/- 1.9	44.6 +/- 21.1	53.0 +/- 19.8
Max diameter (mm)	29.3 +/- 2.1	44.4 +/- 4.9	46.5 +/- 6.4

*one patient w/ aortic stenosis (peak |v| of 2.94 cm/s)

Methods: PCVIPR data were acquired on 1.5T and 3T clinical systems (GE Healthcare, Waukesha, WI) after obtaining informed consent according to our IRB protocol in 11 volunteers and 13 patients with AscAA. Typical scan parameters were: imaging volume = 320 x 320 x 160 mm, readout = 256-320, 1.0-1.25 mm acquired isotropic spatial resolution, VENC of 50-350 cm/s (case specific). Respiratory gating was performed with an adaptive gating scheme based on bellows readings, resulting in a scan time of approximately 10 minutes with 50% respiratory gating efficiency. To reliably achieve high quality images, several correction schemes were applied to account for effects of T1-saturation, trajectory errors, motion, and aliasing associated with undersampling. Segmentation of the aorta was performed with image processing software (Mimics, Materialise, Leuven, Belgium), and stored in a format specific to a flow visualization software (Ensight, CEI, Apex, NC). Processing steps were developed to allow for interactive cross-sectional analysis for velocities and flows at arbitrary slice orientations in volumetric cine datasets, a feature currently unavailable in medical imaging software. Velocity fields were analyzed in the ascending aorta to provide measurements of peak velocity, mean velocity, and the percentage of velocity orthogonal to the direction of flow at peak systole (tangential percentage). Streamline and particle trace visualization approaches were explored to characterize helical, vortical, and laminar flow patterns within the ascending aorta.

Results: 3D flow visualization revealed helical (9/13) and vortical (4/13) flow patterns in patients with AscAA, while all normal volunteers presented with non-rotational laminar flow (Fig 1). Quantitative evaluation (Table 1) shows lower velocities in patients with AscAA, with an exception to one patient with severe aortic stenosis. The tangential percentage of flow in the ascending aorta was much higher in patients with AscAA than in normals (47.7±20.0% and 4.76±1.9%, respectively; $p<1x10^{-7}$) (Fig 1-D).

Conclusion: Calculating a tangential percentage of flow is an easily obtained value that could be used as an index to quantify the amount of helical or vortical flow and be a marker for aneurysmal growth. Further evaluation is needed to determine the prognostic significance of this technique in relationship to other indices (WSS, size, helicity index).

References: [1] T. A. Hope, et al. JMRI 2007; 26: 1471. [2] Weigang, et al. EJCTS 2007; 34:11. [3] M Markl, et al. J Comput Assist Tomogr 2004; 28: 459. [4] T Gu et al., AJNR 2005; 26, 743.

Acknowledgements : We gratefully acknowledge funding by NIH grant 2R01HL072260-05A1 and GE Healthcare for their assistance and support