

Long term follow-up of patients status post valve-sparing aortic surgery with 4D-flow

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Purpose: Surgical correction of aortic ascending aneurysms is complicated by the development of aneurysms and dissections distal to the graft anastomosis, with reoperation occurring in 5 to 35% of patients (1, 2). This preliminary study attempts to determine if there are abnormal flow patterns in the thoracic aorta that are associated with complications status post Tirone-David valve sparing operations for ascending aortic aneurysms.

Materials and Methods: 12 patients status post Tirone-David valve sparing surgery were imaged in 2003 utilizing 4D flow, or time resolved three dimensional phase contrast MRI, for a separate study (3, 4). Visualization was performed using a 3D visualization software (EnSight, CEI Inc, Apex, NC). Wall shear stress on the inner and outer curvatures of the proximal descending aorta and velocity profiles throughout the thoracic aorta were calculated using a proprietary software (flow tool, University of Freiburg) (5).

Results: On average, patients were followed up for 5.2 years after the MRI and 7.8 years after surgery. Three distinct flow patterns at peak systole were seen in the patient population. Normal laminar flow throughout the thoracic aorta was seen in 4 patients (Figure 1A). The most common flow pattern visualized was the development of peripheral helical flow along the inner curvature of the proximal descending aorta, which was seen in 6 patients (Figure 1B); this peripheral helical flow has been previously described in healthy volunteers (6). In two patients, there was the development of a vertical vortex in the proximal descending aorta in the region of the ductus (Figure 1C, arrow). During the follow-up period, one of these two patients developed a type B Stanford dissection originating in the proximal descending aorta. No other patient developed significant dilatation or dissection during the follow-up period. Also of note, the patient who developed a dissection also had a vertical vortex within the prosthetic ascending aorta graft (Figure 1C, arrowhead). These ascending aortic vertical vortices have previously been seen in patients with ascending aortic aneurysms (6). In this patient compared to the average of the other 11 patients, wall shear stress values were decreased along the outer curvature of the descending aorta (0.18 vs 0.94 N/m²). Additionally, peak velocities in the proximal descending aorta were lower (39 vs 64 cm/s).

Discussion: This is the first long-term follow up study to correlate adverse events to visualized abnormal flow patterns using 4D flow. Although the number of patients is small (n = 12), this preliminary study suggests that abnormal flow patterns in the descending aorta may be associated with the development of dissections in the post-operative population. At this time it is not clear whether the abnormal flow in the ascending aorta or the recirculating vertical vortex in the proximal descending aorta is related to the development of dissection. Additional long-term follow up studies need to be performed in order to determine if these are appropriate markers for risk stratification for possible increased follow-up and tighter blood pressure control.

References: 1. Girdauskas et al. *Ann Thorac Surg*, 2008. 2. Erentug et al. *Journal of cardiac surgery*, 2006. 3. Markl et al. *MRM*, 2003. 4. Markl et al. *JTCVS*, 2005. 5. Stalder et al. *MRM* 2008. 6. Hope et al. *JMRI*, 2007.

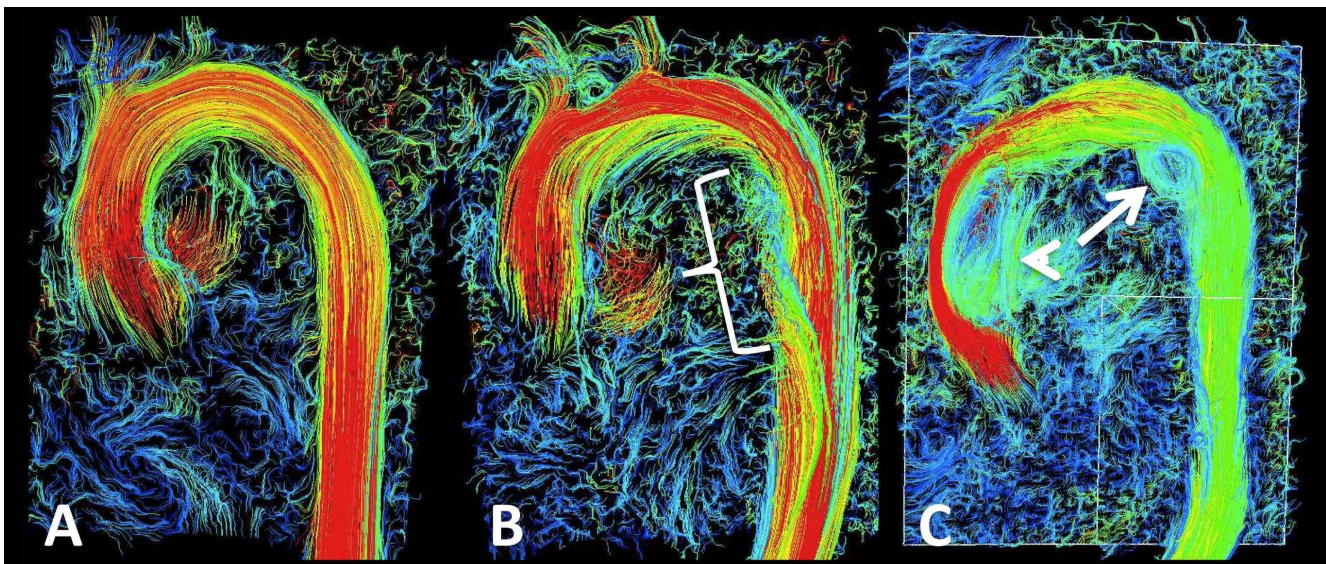


Figure 1: Streamlines through the thoracic aorta at peak systole. A: example of 'normal' flow through, note the laminar nature throughout. B: example of proximal descending aorta inner curvature helical flow (bracket). C: example of vertical vortex in both the ascending aorta (arrow head) and in the proximal descending aorta (arrow).