Flow acceleration and elevated wall shear stress with hypoplastic arch after aortic coarctation repair

T. A. Hope[1], S. E. Crook[1], and M. D. Hope[1]
[1]Radiology, University of California San Francisco, San Francisco, CA, United States

Background: Aneurysm formation at the patch repair site is a known complication status post repair of aortic coarctation (Mendelsohn 1992). It has been shown that there is a strong correlation between aneurysm formation in this population and those who have a hypoplastic transverse aortic arches (Bogaert 1995). Hypoplasia of the transverse arch is defined as a transverse arch diameter to diaphragmatic aortic diameter ratio which measures less than 0.9 (Pinzon 1991). It was proposed that the abnormal narrowing in the transverse aortic arch results in abnormal flow phenomena that contributes to aneurysm formation at the repair site. This study utilizes three-dimensional time resolved phase contrast MRI (4D Flow) to determine if there are abnormal flow features associated with a hypoplastic arch which may help explain this increased risk of aneurysm formation.
Methods: This study was approved by the local institution review board. Four patients with hypoplastic transverse aortic arches were imaged using 4D Flow as previously described (Markl 2003). Additionally four normal volunteers were chosen for comparison purposes. Parallel imaging with a reduction factor of 2 was used to decrease the total scan time (Bammer 2007). Visualization was performed using a 3D visualization software (EnSight, CEI Inc. Apex, NC). Wall shear stress along the thoracic aorta was estimated along a plane placed in the proximal descending aorta using a proprietary software (flow tool, University of Freiburg) (Stalder 2008).
Results: 4D Flow demonstrated abnormal flow in patients with hypoplastic transverse aortic arches in comparison to normal volunteers (example comparison Figure 1). The abnormal geometry results in accelerated velocities and eccentric systolic flow causing skewed elevated wall shear stress along the outer curvature. After coarctation repair, abnormal flow is again seen in patients with hypoplastic arches, and was seen in patients with aneurismal dilation in the region of coarcation repair (Figure 2).
Discussion: 4D Flow demonstrates flow acceleration with hypoplastic arch resulting in asymmetric and elevated aortic wall shear stress at the coarctation repair site, which may predispose to aneurysm formation. These findings may help to explain the high incidence of aneurysms after coarcation repair in this population, and may help prospectively identify these patients before aneurysm formation.
References: Mendelsohn AM et al. J Am Coll Cardiol, 1992; Bogaert et al. J Am Coll Cardiol, 1995; Pinzon JL et al. Radiology, 1991; Markl M et al. MRM, 2003; Bammer R et al. MRM, 2007; Stalder et al. MRM, 2008.

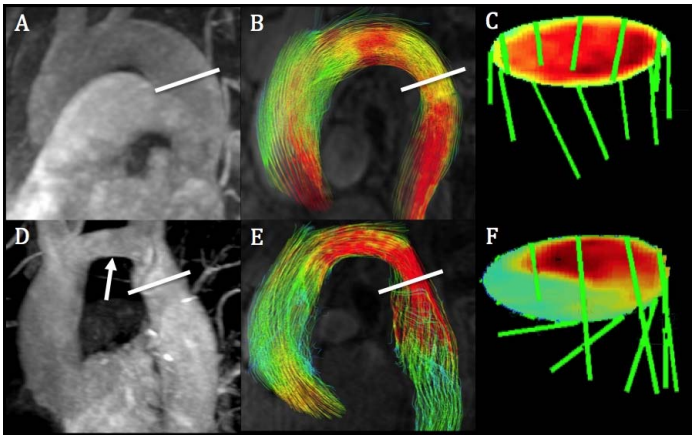

Figure 1: (A) MIP from an MRA in a normal volunteer with unremarkable laminar flow as shown by streamlines during mid systole (B) and associated symmetric wall shear stress in the proximal descending aorta (C). (D) shows a MIP from an MRA in a patient with a hypoplastic aortic arch (arrow) which demonstrates abnormal acceleration of eccentric systolic flow into the proximal descending aorta (E) resulting in abnormally elevated wall shear stress along the outer curvature (F).

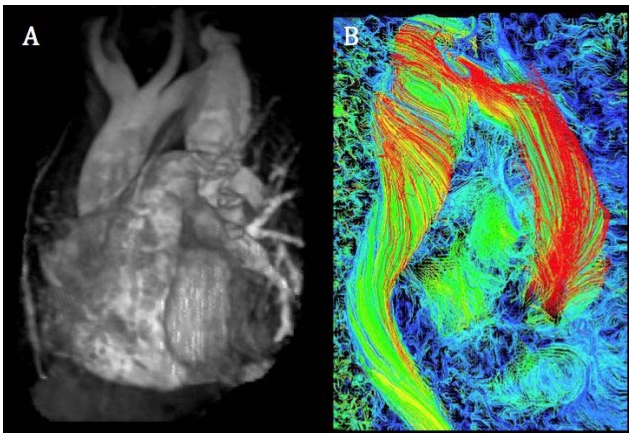

Figure 2: (A) MIP from an MRA in a patient status post coarctation repair with a hypoplastic transverse aortic arch. Aneurismal dilatation of the proximal descending aorta as well as abnormal flow in the region of the repair site can be seen (B).