Four-Dimensional Flow Magnetic Resonance Imaging With Wall Shear Stress Analysis Before and After Repair of Aortopulmonary Fistula

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We used 4D flow magnetic resonance imaging\(^1\) to evaluate a 34-year-old man with a complicated course after aortic coarctation repair including development of an aortopulmonary fistula. Our initial 4D flow study (Figure 1) reveals abnormal vortical-type flow in the aneurysmal distal aortic arch. Evaluation of wall shear stress calculated from near-wall velocity gradients using proprietary software (flow\(^\text{tool}\), University of Freiburg, Germany; software is experimental and not FDA approved)\(^2\) demonstrates skewing of higher shear values along the posterior and left lateral aortic arch, just upstream of a pseudoaneurysm.

Two months after this study, the patient presented with hemoptysis and was shown to have an aortopulmonary fistula between the pseudoaneurysm and left upper lobe. Surgical treatment with a left upper lobectomy and repair of the aneurysm with interposition graft was performed. Follow-up 4D flow imaging 4.5 months after surgery (Figure 2) shows smaller dimensions of the distal arch and proximal descending aorta after repair, with significantly decreased circular systolic flow in this region. The velocity profile is more central, and the distribution of wall shear stress is less skewed, with relatively uniform values involving all but the inner curvature.

Our group and others have observed abnormal helical and vortical-type flow after coarctation repair,\(^3\) but the clinical significance of these findings is unknown. This case suggests that a consequence of vortical-type flow is marginalization of the systolic flow stream, resulting in an uneven distribution of hemodynamic burden in the form of elevated wall shear stress along the aortic wall, which may promote and/or exacerbate vascular pathology.\(^4\) Additionally, this case exhibits how 4D flow can be used to assess postoperative physiology by demonstrating clear changes in blood flow and wall shear stress after surgical repair.

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Disclosures
None.

References
Figure 1. A 34-year-old man with complicated course status after aortic coarctation repair. A, 3D contrast-enhanced magnetic resonance imaging that demonstrates an aneurysm of the distal aortic arch extending to the descending aorta, with a small left posterolateral saccular outpouching (red arrow), or pseudoaneurysm. Subsequent to this study, the patient had an aortopulmonary fistula at this location. B, Right-sided view of the aortic arch with streamlines to visualize the 4D flow data set in midsystole. Streamlines are color-coded for velocity. Marked vortical-type flow is seen along the inner curvature of the aneurysm with marginalization of high-velocity flow along the outer curvature, just upstream of the pseudoaneurysm. C, Velocity profile for the 2D plane represented in A and B that shows skewing of high-velocity flow toward the left posterolateral aortic arch. D, Systolic wall shear stress for 12 annular segments along the circumference of the aorta for this 2D plane. Higher shear stress values are seen in the posterior and left aspects of the aorta. Note that color-coded velocity has been mapped onto the 2D plane. Green bars represent shear stress values in N/m², with the highest values along the outer curvature (1.3 N/m² at segment 7) and the lowest along the inner curvature (0.14 N/m² at segment 11).
Figure 2. Analysis identical to Figure 1 after repair of aneurysm and aortopulmonary fistula. A, Smaller dimensions of the distal arch and proximal descending aorta after repair of the aneurysm with interposition graft. B, Significantly reduced circular flow in the aortic arch during systole. C, More central velocity profile. D, Less skewed distribution of shear stress values, with relatively uniform values involving all but the inner curvature; values ranged from 0.49 to 0.86 N/m² for segments 2 through 9.
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