Visualization of vortex flow and shear stress in the aortic root during left ventricular assist device support

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Progression of aortic valve insufficiency significantly compromises hemodynamics in patients with advanced cardiac failure receiving left ventricular assist device (LVAD) support. Nonphysiologic shear stress in the aortic valve produced by collision of the continuous retrograde blood flow from the LVAD has been suggested to induce

![Video clip is available online.](image)

![Supplemental material is available online.](image)

Retrograde blood flow from the LVAD Increases the wall shear stress on aortic valve leaflets.

**Central Message**

We visualized the retrograde blood flow in the ascending aorta in the patient under continuous-flow left ventricular assist device support, which developed into a vortex producing shear stress on the aortic valve leaflets.

See Editorial Commentary page 879.

**FIGURE 1.** *(Left)* Flow velocity vector on color Doppler. Red represents flow toward the top; blue, flow toward the bottom. The yellow arrow represents the flow velocity vector, with the direction of the arrow equal to the flow direction and the size of arrow reflecting flow velocity. *(Right)* The fine green lines indicate the flow streamline. Multiple colors around the aortic root represent the wall shear stress: red, high; blue, low. A, Systolic phase. B-E, Early and mid-diastolic phases. F, Late diastolic phase.
valve leaflet thinning and, consequently, aortic valve insufficiency and its progression, although computational fluid dynamics to visualize blood flow in the aortic root has not been established because of its complex anatomy, such as the origin of the coronary arteries. We clearly visualized the blood flow in the aortic root in patients under LVAD support by conducting an echocardiographic study with vector flow mapping analysis (DAS-RS1).

Here we present images of a case of ischemic dilated cardiomyopathy in a 40-year-old woman just after implantation of a continuous-flow LVAD (HeartMate II; Thoratec, Pleasanton, Calif) (Figure E1). The blood flow in the ascending aorta showed pulsatility from the beating of the left ventricle, which increased blood flow via the LVAD without opening the aortic valve. During systole, retrograde blood flow was clearly visualized in the ascending aorta, and shear stress increased in the posterior wall of the ascending aorta (Figure 1, A). Blood flow then developed into a vortex in the aortic root, moving toward the aortic valve with magnified vorticity, consequently producing shear stress on the aortic valve leaflets (Figure 1, B-E). In the late diastolic phase, the vortex moved distally with its vorticity settled (Figure 1, F; Figure 2, A and B; and Video 1).

Blood flow through the aortic valve may alter the vortex size and/or vorticity in the aortic root, potentially decreasing the shear stress in the aortic valve. Further studies are needed to evaluate case-dependent differences in blood flow to demonstrate the mechanisms underlying the initiation and progression of aortic valve insufficiency after LVAD implantation.

References
FIGURE E1. A, LVAD outflow graft anastomosed to the anterior wall of the ascending aorta. B, Postoperative anatomy, including the outflow graft, the ascending aorta, and the aortic valve.