Left Heart Inflow Abnormalities: Intraventricular Image-Based CFD With Wall Motion and MRI Boundary Conditions

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Background Hypertrophic obstructive cardiomyopathy (HOCM) is a complex myocardial disease characterized by asymmetric septal hypertrophy and systolic anterior motion of the mitral valve leaflet, leading to dynamic left ventricular outflow tract (LVOT) obstruction. While computational fluid dynamics (CFD) has been widely applied to study intraventricular flow in HOCM, the mechanistic coupling between cardiac morphology, wall motion, and downstream hemodynamics remains incompletely understood.

Methods An image-based *morphodynamic* framework was developed to quantify ventricular–valvular interaction in HOCM. Here, morphodynamics denotes the coupled interaction between cardiac geometry, time-varying wall and valve motion, and the resulting blood-flow organization, emphasizing how deformation actively shapes flow acceleration, jet formation, and wall shear stress distributions. Patient-specific geometries of the left ventricle, mitral valve apparatus, aortic valve, and aortic root were reconstructed from time-resolved clinical CT imaging. Deformable surface registration was used to extract regional myocardial and valvular motion, which was coupled with CFD simulations to resolve systolic hemodynamics.

Results The results demonstrate that LVOT obstruction arises from coupled geometric and kinematic mechanisms rather than static anatomy alone. Reduced basal septal motion, anterior papillary muscle displacement, and asymmetric valve morphology promoted Venturi-driven flow acceleration, skewed systolic jets, and localized elevations in wall shear stress on both the ventricular septum and aortic valve leaflets.

Conclusion This morphodynamic analysis provides mechanistic insight into ventricular–valvular coupling in HOCM and establishes a foundation for patient-specific assessment tools to support disease characterization and surgical planning.