Image-Based CFD Analysis of Inflow–Outflow Interaction and Aortic Root Hemodynamics in Hypertrophic Obstructive Cardiomyopathy

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Background Hypertrophic obstructive cardiomyopathy (HOCM) is characterized by dynamic left ventricular outflow tract (LVOT) obstruction driven by septal hypertrophy and systolic anterior motion of the mitral valve. While intraventricular flow alterations in HOCM are well documented, the effect of LVOT obstruction on aortic valve and aortic root hemodynamics remains incompletely understood when realistic chamber motion and valve kinematics are considered.

Methods An image-based computational fluid dynamics (CFD) framework was developed using a complete patient-specific left-heart model reconstructed from 4D computed tomography. Ventricular and atrial geometries, wall motion, and fully resolved mitral and aortic valve anatomy and kinematics were incorporated. Unsteady CFD simulations were performed using a moving-mesh solver, and systolic velocity fields, pressure gradients, and wall shear stress (WSS) distributions were analyzed.

Results The simulations reproduced hallmark HOCM features, including dynamic LVOT narrowing, a Venturi-driven systolic jet, elevated septal WSS, and a pronounced trans-LVOT pressure drop. The LVOT jet propagated into the aortic root, generating asymmetric flow through the aortic valve. Post-valvular flow was deflected away from the left coronary sinus, resulting in reduced sinus washout and non-uniform leaflet WSS with peak loading near the leaflet tips.

Conclusion These findings demonstrate that realistic inflow–outflow coupling in HOCM substantially alters aortic valve and root hemodynamics, with potential implications for coronary perfusion and valve dysfunction. The proposed framework enables mechanistic, patient-specific assessment of inflow-outl interaction in HOCM.