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Computer Finite-Element Simulations of Remodeling and Re-Implantation for Aortic Root Aneurysm

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Root aneurysm leads to abnormal aortic valve (AV) mechanical-structural performance with larger deformation gradients and stresses. Current AV computational models are somewhat qualitative and do not capture the local complex nonlinear tissue and structural behaviors. Nonlinear multiscale (heterogeneous) material and structural (MMS) models have been developed in this study in order to simulate normal and abnormal mechanical behavior of the AV structure. The overall goal is to introduce predictive simulations of native and porcine AV's initially under in vitro pulsatile flow conditions. The proposed predictive modeling framework is verified using sophisticated imagery measurements to examine the kinematics and deformations of normal AV systems. A major aspect of this study is to employ these computational models for AV pathology and repair. Towards that goal, select repair procedures, such as root re-implantation and re-modeling are simulated and examined computationally. Preliminary simulation results demonstrate that the computational model is capable of capturing the geometrical changes (strains) on the leaflet along with the induced stresses during the different stages of the sparing procedure, i.e. extracting the enlarged sinus tissue; installing the graft; suturing the tissue; and imposing different transvalvular pressure-profiles for the cardiac cycle. It is shown that the changes in the leaflet geometry in the earlier stages have an impact on the AV performance and should be considered in a progressive-sequential manner. The proposed AV-MMS approach is important towards imagery-based diagnostics and repair design of the AV.