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Two-Layer Passive/Active Anisotropic FSI Models with Fiber Orientation: MRI-Based Patient-Specific Right Ventricle Models for Pulmonary Valve Insertion Surgery Design

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Summary

A single-layer isotropic patient-specific right/left ventricle and patch (RV/LV/-Patch) combination model with fluid-structure interactions (FSI) was introduced in our previous papers to evaluate and optimize human pulmonary valve replacement/insertion (PVR) surgical procedure and patch design. In this paper, an active anisotropic model with two-layer structure for ventricle wall and tissue fiber orientation was introduced to improve previous isotropic model for more accurate assessment of RV function and potential application in PVR surgery and patch design. A material-stiffening approach was used to model active heart contraction. The computational models were used to conduct "virtual (computational)" surgeries and test the hypothesis that a PVR surgical design with a smaller patch and more aggressive scar tissue trimming would lead to improved RV cardiac function recovery. Results from our models validated by pre-operation data indicated that the small patch design had 11% improvement in RV function as measured by RV ejection fraction, compared to the conventional patch. Maximum Stress-P_1 value from the active anisotropic model was 121.2% higher than that from the passive isotropic model. Computational RV volume predictions agreed well with CMR-measured volume data (error $< 2\%$).

keywords: right ventricle, congenital heart disease, Tetralogy of Fallot, heart model, fluid-structure interaction.

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