MCB, vol. 16, supplemental 1, pp.41, 2019

Echo-Based FSI Models to Simulate Ventricular Electrical Signal Conduction in Pig Pacemaker Models

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Abstract: Cardiac pacing has been an effective treatment in the management of patients with arrhythmia. Different pacemaker location may have different impact on pacemaker effectiveness. A novel image-based ventricle animal modeling approach was proposed to integrate echocardiography images, propagating dynamic electric potential on ventricle surface to perform myocardial function assessment. The models will be used to simulate ventricular electrical signal conduction and optimize pacemaker location for better cardiac outcome. One health female adult pig weight 42.5 kg was used to make pacing animal model with different ventricle pacing locations. Pig health status was assessed before undergoing experimental procedures. Ventricle surface electric signal, blood pressure and echo image were acquired 15 minutes after the pacemaker was implanted. Echo-based left ventricle (LV) fluid-structure interaction (FSI) models were constructed to perform ventricle function analysis and investigate impact of pacemaker location on cardiac outcome. The nonlinear Mooney-Rivlin model was used for ventricle tissue material model. With the measured electric signal map from the pig associated with the actual pacemaker site, electric potential conduction of myocardium was modeled by material stiffening and softening in our model, with stiffening simulating contraction and softening simulating relaxation. Material stiffness parameters were adjusted in a cardiac cycle to match Echo-measured LV deformation and volume variations. Mapping between material stiffness and ventricle electric signal was quantified using data measured from the animal with different pacemaker locations. Ventricle model without pacemaker and three ventricle models with the following pacemaker locations were simulated: right ventricular apex (RVA), posterior interventricular septum (PIVS) and right ventricular outflow tract (RVOT). Data for ventricle volume change, ejection fraction, stress and strain, flow velocity and shear stress data were collected for comparisons. Our results demonstrating that PIVS pacing model had higher peak flow velocity and stress/strain. It indicated that PIVS pacemaker site may be the best location. This modeling approach could be used as "virtual surgery" to try various pacemaker locations and avoid risky and dangerous surgical experiments on real patients.

Keywords: Fluid-structure interaction model, pacemaker electrical conduction, Fluid dynamic, ventricle material properties, ventricle mechanics.

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