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LINKING BIOPHYSICAL MUSCLE MODELS WITH FINITE ELEMENT SOLVER

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ABSTRACT

Understanding the effects of structural and kinetics changes of sarcomeric proteins at the level on muscle cells or tissue requires detailed and comprehansive biophysical muscle models, such as MUSICO [1]. However, these models require large computational resources to track all molecular interactions. Thus, they are, in most cases, impractical for use in finite element solvers. To resolve this problem we have developed Mijailovich-Prodanovich (MP) surrogate model that is reduced to a system of ordinary differential equations and uses parameters that replicate transient responses obtained by detailed comprehansive models. This approach is computationally effective for use in finite element solvers and provides tools to translate changes accross the length scales, i.e. from modulated molecular interactions to changes in functional behavior at the level of muscle cells and tissues. To demonstrate ability of this novel approach we have implemented the MP surrogate model into finite element solver PAK [2,3] to provide calculations of active tension and changes in muscle stiffness during (cardiac) muscle transient contractions. At a macro level, finite element solver PAK provides stretches along muscle fibers as a feedback loop to the MP model. Passive stresses, obtained from the recently implemented Holzapfel experimental material model [3], are also included in the calculation of total stress. Moreover, openMP library is incorporated in the multiscale model, which is typically used for loop-level parallelism, to speed up the calculations of integrated PAK-MP simulations. With the MP model integrated into the finite element solver PAK, we tracked the effects of several drugs, i.e., digoxin, disopyramide and mavacamten, on the cardiac muscle contraction of left ventricle. Simulations showed increase of ejection fraction, changes in outlet velocities and improvements in pressures and volumes. With pressure-volume diagrams, produced by our coupled simulations, we can help evaluate any realistic or

hypothetic clinical scenario, and potentially guide the treatment of patients with cardiac muscle diseases and disorders.

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