One-dimensional Simulation of Transmural Heterogeneity of Cardiac Cellular Electromechanics

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Cardiac tissue exhibits transmural heterogeneous electromechanical characteristics which are responsible for normal activation, repolarization, contraction and relaxation in healthy hearts. Under abnormal conditions such as myocardial ischemia, the original heterogeneity will be disrupted and may cause the heart out of function. In this paper, a transmural heterogeneous cellular electromechanics model has been developed based on the Greensteins canine ventricular M cell model and Rices myofilament model together with recent experiment data. We used the model to simulate and validate transmural heterogeneity of the electrical properties such as action potential duration, rate dependence, intracellular ionic concentrations (especially Ca2+) and mechanical properties like latency to onset of contraction, duration, the time to peak and so on. In addition, the developed model was also used to simulate ventricular electrocardiograms under normal and ischemia conditions on the multicellular 1-D fiber model which includes endocardial, M and epicardial cells like the ventricular tissues. Abnormal conditions of myocardial ischemia, hyperkalemia, acidosis and hypoxia were simulated. The results show that our model could reproduce many transmural heterogeneous electromechanical features of the heart, and were in good accordance with experimental observations. The electrocardiograms under normal and ischemia conditions were compared to demonstrate the importance of the precise transmural heterogeneity. The present model could be integrated into 2-D and 3-D ventricular tissues for further researches.