

An integrative model of heart and coronary circulation to delineate the effect of coronary occlusion on heart electric conduction

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Abstract

An integrated model of heart coupling excitation-contraction (EC) of cardiac cell, tissue electric conduction, and coronary artery hemodynamics is proposed for analyzing the effect of coronary artery occlusion on heart electric conduction (Figure 1). For this purpose, we developed a comprehensive ventricular electric conduction-coronary hemodynamic coupled model with multi-physics and multi-scale characteristics that simulates the physiological events from membrane excitation of a cardiac cell to heart electric conduction, coronary blood circulation. To simulate the interaction between stenosed coronary artery and cardiac cellular electrophysiology, a cellular model (with mitochondria model and K-ATP channel) (Figure 2) and the coronary hemodynamic model with microcirculatory compartment was incorporated into ventricular model. Computational fluid dynamics (CFD) model (Figure 3) and mono-domain method are used to compute the coronary blood flow and electric wave conduction on heart, respectively. We used a finite element method and the Galerkin approximation to discretize the three-dimensional (3-D) domain spatially. Using the model, we delineated the physiological interaction between heart electric waves and coronary circulation. Computed results showed that heart electric waves were influenced by coronary artery hemodynamics (Figure 4). Elevated ST level of pseudo-ECG was found near heart apex when left anterior descending (LAD) artery was occluded. Especially we also showed that inhibition of oxygen supply to cardiac cell due to coronary artery occlusion may cause reentry waves, leading to tachycardia and fibrillation.

Key Words: Integrative modeling, Heart and coronary circulation, Coronary occlusion, Heart electric conduction

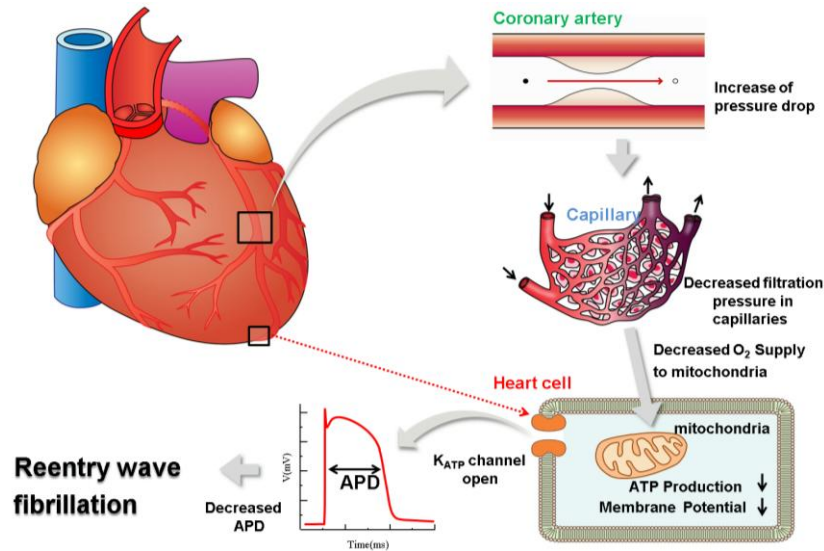


Figure 1 Schematic of the interaction between coronary artery stenosis and heart electric conduction.

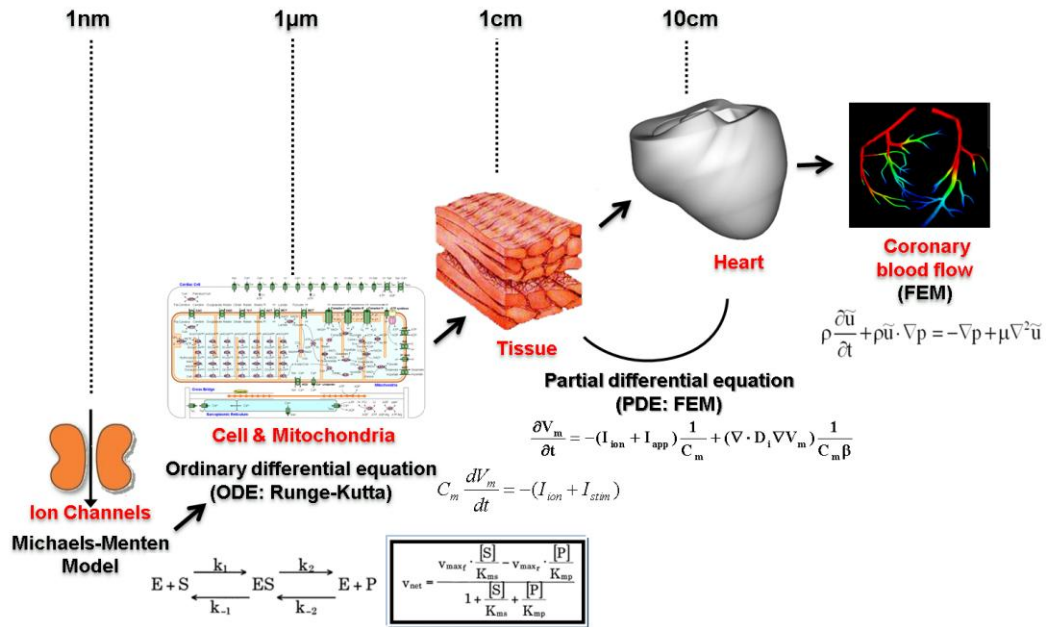


Figure 2 Schematic of the integrative model of heart and coronary circulation to delineate the effect of coronary occlusion on heart electric conduction.

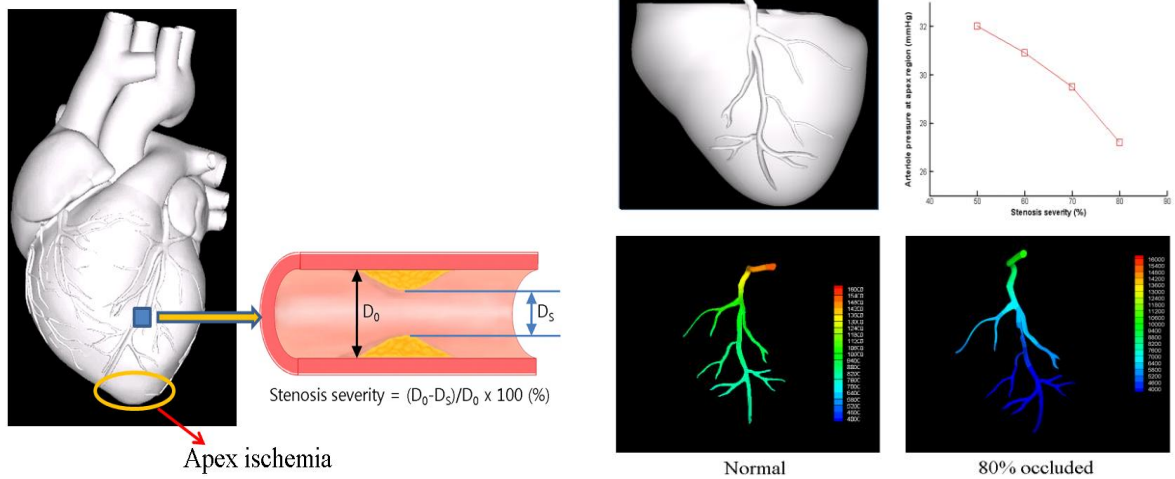


Figure 3 Schematic model and computed results of coronary artery hemodynamics.

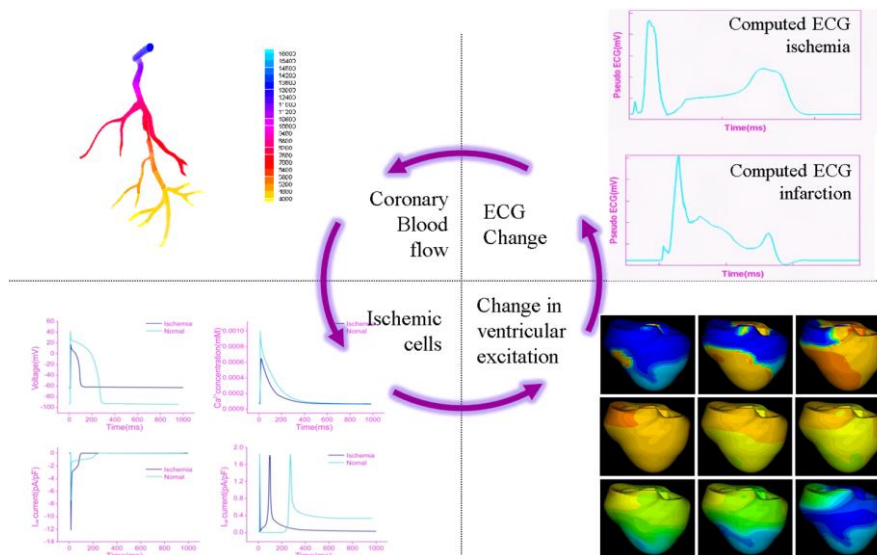


Figure 4 Computed results showing that heart electric waves were influenced by coronary artery hemodynamics. Elevated ST level of pseudo-ECG was found near heart apex when left anterior descending (LAD) artery was occluded.