Utilization of a computational cardiac electromechanics for mechano-electric feedback

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Abstract

The heart, core of the cardiovascular system, circulates the blood in order to provide every single cell with the essential nutritions. As the ceaseless beats of the human heart are crucial, any disorder in the heart might lead to the loss of life quality, and even sudden death. Extensive effort has been done to reduce the mortality and the economical side effects by means of experimental and clinical studies. However, due to the limitations of experimental studies, the trend of research on cardiovascular system is moving onto the computational cardiac modeling based on the finite element method (FEM). In the context, computational cardiology and modeling of the heart might help the comprehension in accomplishing more effective therapies. To this end, computational models have been established to simulate the electromechanics of the heart.

The heart's pumping action can be successfully performed by the well-coordinated relationship between Excitation Contraction Coupling (ECC) by which electrical activation of cardiac cells triggers the mechanical contraction of the heart and Mechano Electric Feedback (MEF), a mechanical alteration influences cardiac electrical activity. While ECC is rather well characterized, less is known about the cellular mechanisms of MEF. Nevertheless, the significance of MEF cannot be disregarded. In the work, MEF is computationally investigated on cell and organ scales by using the modified Hill model describing the orthotropic electro-visco-elastic response of the myocardium where the active (electrical) and mechanical (viscous and elastic) deformations are decomposed in a multiplicative format [1, 2]. At cell scale, it is revealed that MEF contributes to the synchronized contractions of the cardiac tissue by decreasing the dispersion of repolarization. The influence on the biventricular heart model is studied by the electrocardiogram (ECG) and the volume-time curve (v-t curve) during normal cardiac cycles. It is observed that MEF is activated in the different areas of the biventricular heart. Afterwards, ventricular fibrillation by application of the physical impact on the heart is simulated. Finally, Premature Ventricular Contractions (PVC) are simulated by the hemodynamical disturbance by using the left ventricular heart model. The adverse influence of the PVC on the cardiac performance is studied and post-extra-systolic Potentiation (PESP) is detected during the PVC.

Keywords: *Finite element method, computational electromechanics, modified hill model, mechano-electric feedback*

References

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