Title: Towards the integration of in-silico cardiovascular system, vessel and electro-chemo-mechanical smooth muscle cell models

Authors:
Jose Suihkonen, Francesca Menna, Nicole Anderton, Joan Duprez, Jussi T Koivumaki, Virginie Le Rolle, and Jari Hyttinen

Keywords:
Cardiovascular model, passive properties, vascular tone,

Abstract

Vascular tonal adaptation to local hemodynamic change is an integral mechanism of both cardiovascular function and control. In 0D-lumped models of the circulatory system, each vessel is often represented by its electrical analogue as a fixed value. This approach does not consider the fact that the vessel wall is composed of passive (ECM, collagen, elastin) and active (smooth muscle cell (SMC)) elements that modulate vessel diameter, which ultimately affect vessel resistance and compliance, and control blood flow and pressure. This leaves a gap in our understanding and ability to predict and manage cardiovascular disease progression. We aim to begin addressing this knowledge gap by coupling, in-silico a detailed cardiovascular model with an electro-chemo-mechanical SMC model, through a reduced order vessel model. The mean flow and pressure profiles of the system level model, as well as the contractile state of the smooth muscle cell, are fed into the vessel model. The vessel model's adaptive stretch is feed back into the SMC, while the vessel's changing diameter is used to calculate resistance and compliance values that are fed back into the system level model. The model behaviours are demonstrated for the left main coronary artery of a virtual patient with varied degrees of obstruction. Our first coupled model improved the mechanical representation of the vessel by considering the effect of the passive properties of the vessel wall on blood flow and pressure. Future work will be done include the effect of SMC contraction on the active properties of the vessel wall.