Vessel Biomechanics and Smooth Muscle Active Force in the Coronary Circulation: A Computational Model

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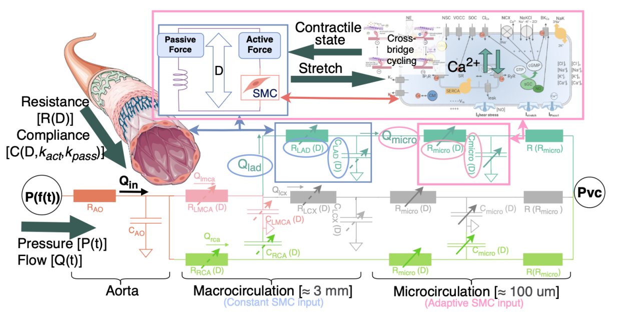
Context and aim: The coronary circulation comprises multiple highly interdependent subsystems that control blood pressure and flow. These components are multiscale, spanning several spatial and temporal levels. No model has thus far captured the true multi-layer complexity of the coronary circulation. We aim to address this knowledge gap by observing the whole system response of a novel, coupled, multilevel model of the coronary circulation.

Methods: In-silico, we integrated and studied a coronary lumped-parameter model with vessel wall mechanics. At the microvascular level, an electro-chemo-mechanical smooth muscle cell (SMC) model with adaptive contractile state was added to drive vessel active tension.



Results and conclusions: The new integrated model demonstrates successful multi-scale coupling, with the vessel wall biomechanics and active SMC stretch-related contractile states adapting vessel diameter, resistance, and compliance to pressure and frequency change. For a pressure change of 100 to 60 mmHg, the large arteries exhibit a jump in resistance of 19%, and compliance of 40%, whilst a more limited resistance of 8% and compliance of 18% response is observed in the microcirculation. This shows that the SMCs significantly influences the Windkessel effect. The impacts of ventricular force generation, shear-stress driven Nitric Oxide relaxation pathways, energy driven dynamics, microcirculation branching, systemic circulation, and hormonal influences will be studied in future work.