A Physiologically Accurate Active Strain Model for Left Ventricular Contraction

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Abstract:
Modelling the mechanical properties of the myocardium such as the passive and active responses is an essential component of mathematical cardiac models. Often, passive myocardium is considered to be anisotropic and hyperelastic, and its contractile function is usually modelled by an active stress approach. This is where the total stress is obtained by adding the passive and active stress tensors together. Another method to model myocardial contraction is the active strain approach, where the deformation gradient is multiplicatively decomposed into passive and active components to overcome the issues of mathematical convexity arising from the active stress approach. Furthermore, the active stress approach is rather phenomenological, while the active strain approach depends on local distortions that relate to the microstructure of myofilaments, by signifying the sequential order between active distortion and elastic stretch. In this work, we introduce a new active strain model that is
physiologically accurate with parameters that could be calibrated from measured data. By further incorporating a limiting function on the elastic stretch that a living myocyte can experience, the new active strain model can accommodate different levels of active contraction. An existing left ventricular model is then used to simulate realistic left ventricular pump function, which is implemented with an immersed boundary method with finite element extension. We compare the new active strain model with the active stress approach using the same left ventricular model. Results suggest that the new active strain model can simulate left ventricular dynamics as effectively as the active stress model, with subtle differences in fibre stress, despite the two models being fundamentally different. Future studies will apply this new active strain model to patients for personalised modelling.