Homogenized modelling of the electro-mechanical behaviour of a vascularized poroelastic composite representing the myocardium

Laura Miller, Raimondo Penta
University of Strathclyde, Mathematics and Statistics

Abstract:
We propose a novel model for a vascularized poroelastic composite representing the myocardium which incorporates both mechanical deformations and electrical conductivity. Our structure comprises a vascularized poroelastic extracellular matrix with embedded elastic inclusions (representing the myocytes) and we consider the electrical conductance between these two solid compartments. There is a distinct length scale separation between the scale where we can visibly see the connected fluid compartment separated from the poroelastic matrix and the elastic myocyte and the overall size of the heart muscle. We therefore apply the asymptotic homogenisation technique to derive the new model. The effective governing equations that we obtain describe the behaviour of the myocardium in terms of the zero-th order stresses, current densities, relative fluidâ€"solid velocities, pressures, electric potentials and elastic displacements. It effectively accounts for the fluid filling in the pores of th e poroelastic matrix, flow in the vessels, the transport of fluid between the vessels and the matrix, and the elastic deformation and electrical conductance between the poroelastic matrix and the myocyte. This work paves the way towards a myocardium model that incorporates multiscale deformations and electrical conductivity whilst also considering the effects of the vascularisation and indeed the impact on mechanotransduction.