Analyzing the fiber effects of combining different Laplace-Dirichlet rule-based methods for simulating heart electromechanics

Roberto Piersanti, Luca Dede', Natalia Trayanova, Alfio Quarteroni

[1]MOX - Laboratory of Modeling and Scientific Computing, Dipartimento di Matematica, Politecnico di Milano, Milano, Italy

Accurately representing cardiac fiber architecture, dictated by myofiber orientations, is a critical aspect of building cardiac computational models (CCM) and is essential for characterizing the cardiac tissue. The collective organization of myofibers plays a pivotal role in both the electric signal propagation and the mechanical contraction of the heart. Therefore, it is imperative to incorporate accurate cardiac fibers in CCM. Due to the difficulty of reconstructing cardiac fibers from medical imaging, a prevalent approach for fiber prescription in CCM is through mathematical models. Current methodologies include rule-based methods (RBMs), which mainly employ semi-automatic techniques to manually prescribe fiber orientations in specific cardiac regions, and atlas-based methods (ABMs), where fibers are mapped from a reference geometry to a target one. Both methods necessitate manual intervention and are usually customized for particular morphologies. Recently, advanced Laplace-Dirichlet-RBMs (LDRBMs) have emerged, demonstrating potential in automatically generating fiber architecture across diverse morphologies. However, these innovative algorithms may overlook critical fiber bundles, particularly in the atrial chamber. This study introduces an improved total heart LDRBM, combining different ventricular and atrial models, capable of prescribing a biophysically detailed, chamber-specific, and volumetric fiber architecture. Furthermore, it presents a novel methodology for prescribing myofiber dispersion in cardiac fibers. We systematically compare various LDRBMs for the atria and ventricles and analyze the results using meaningful biomarkers derived from numerical electromechanics (EM) simulations. Specifically, we investigate differences among methodologies for reconstructing cardiac architecture. Lastly, we analyze different arrangements in cross-fiber mechanical contraction, highlighting the impact of using different fiber fields in EM simulations.