Data

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1. Background

Current non-invasive methods for myocardial viability assessment for diagnosis and monitoring have shown limited success in faithfully characterizing biomechanical and electrical cardiac activity. Methods for measuring electrical data, such as invasive in vivo electrophysiology studies, are disruptive to normal tissue function and thus ill-suited for in vivo use. Similarly, there also exists no means to directly measure cardiac mechanics (i.e., active stresses developed within myocardial tissue). However, it is common to quantify heart motion using medical imaging and employ image processing tools to estimate myocardial displacements. Hence, the reconstruction of active stresses and electrical data from myocardial tissue displacements is the missing piece.

2. Methods

We have proposed a technique to reconstruct active stresses from motion data. However, the inherent uncertainty associated with estimated tissue displacements poses significant challenges. Using the mechanical model by Otani et al., which takes advantage of specific active stress properties of myocardial fibers, paired with FitzHugh-Nagumo's (FHN) electrical model, we implemented a forward model that yields motion data. To solve the inverse problem, we implemented an Ensemble Transform Kalman Filter (ETKF)-based technique that simulates system dynamics alongside displacement data, significantly diminishing the impact of displacement uncertainties on the reconstruction.

3. Results

The proposed ETKF inverse problem solution significantly reduces error variance compared to the naïve least-squares solution. The ETKF-based mean errors were -0.0051+/-0.2977, while those obtained using the least-square solution were -0.0002+/-5.2173. We also reconstructed the active stresses and action potentials associated with spiral wave dynamics and showed successful cardiac electro-dynamics reconstruction for action potentials propagating along the tissue fibers.

4. Conclusions

We describe a technique that enables robust reconstruction of cardiac active stress and action potentials from myocardial displacement data. Future efforts will focus on improving computational performance and extending the work to realistic, imaging-based patient-specific myocardial models.