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MYOCARDIAL MATERIAL PARAMETER ESTIMATION IN THE PRESENCE OF UNKNOWN BOUNDARY TRACTIONS

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Myocardial stiffness is a potential biomarker for the stratification of heart failure. Its estimation in the clinic currently relies on cavity pressure-volume analysis, which cannot quantify changes in regional material properties of the myocardium during remodelling. In recent years, the personalisation of anatomical biomechanical models has been proposed for estimating regional myocardial stiffness, through the estimation of the material parameters in the constitutive equations employed in the finite element model. Myocardial material parameter estimation in this framework suffers from limited parameter identifiability, where multiple parameter combinations result in equivalent cost function residuals, thus obstructing the optimisation process. In our previous work [1], we proposed a cost function that ensures unique parameter estimation, based on the principle of mechanical energy balance in the myocardium. However, this formulation is limited by the presence of unknown tractions at the myocardial boundaries.

In this contribution we present a novel approach which overcomes the problem of unknown boundary tractions and ensures unique myocardial parameter estimation from magnetic resonance imaging and pressure catheter data. Our method builds up from previous work, where an improved cost function was proposed based on the principle of virtual works [2]. We have developed a pipeline for constructing suitable virtual fields that optimise the parameter estimation process based on the available data and the selected computational mechanics framework. The feasibility of this method is demonstrated in a series of synthetic data from computational phantoms based on axisymmetric geometries and anatomical data from heart failure patients. Based on our results, the proposed method has improved robustness (200% increase) and accuracy (relative error decreased by 42%).

Our novel framework for myocardial material parameter estimation provides improved identifiability and overcomes the limitations of unknown tractions at the basal and epicardial boundaries. The pipeline involves limited use of computer simulations, thus ensuring computational efficiency and increased potential for clinical translation.

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