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Personalization of synthetic pathological left ventricles using learning-based infarct localization and finite-element inverse modeling

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Introduction

Cardiac ischemia is a condition in which the coronary arteries are narrowed, restricting the blood flow to the heart muscles and causing myocardial infarction (MI). The healing process after MI is called myocardial remodeling, and its prognosis is essential to predict the heart condition [1]. However, the mechanisms involved in myocardial remodeling are still not well understood. Our aim is to gain more understanding of the remodeling process by obtaining personalized indices that relate more to the mechanical functionality of the heart than tissue viability or strain values.

Method

We introduced a personalization approach to better assess the regional myocardial functional status. The approach combines state-of-the-art infarct localization [2] and a novel finite-element (FE) cardiac modeling [3,4]. Based on the personalized model, we propose stiffness-related indices that would provide more information on the heart condition. Fig.1-top describes the proposed personalization approach. From cardiac magnetic resonance (CMR) data, we reconstruct the left ventricle (LV) geometry, extract the strain data, the LV volume and pressure if available. From the strain pattern, abnormal regions are estimated via a learning-based method to partition the LV geometry into healthy and potentially-infarcted regions. Next, we incorporate a rule-based fiber orientation and implement a constitutive law to define the mechanical behavior of the LV [4]. Optimization is finally performed to personalize the material parameters for each case. The objective function is based on the strain data, volume and pressure. Once satisfied, the personalized material parameters are available for each region.

Results

This study verified the feasibility of the approach by applying it to 5 pathological cases obtained from forward modeling of actual LV geometries. Fig.1-bottom compares the ground truth and the results for one case: the infarct prediction (left) and the strain pattern distribution (middle). Fig.1-bottom (right) lists the ground truth and the personalized parameters of the same case. This finding confirms that the suggested approach was able to personalize each case within an acceptable range of accuracy.

Conclusion

We investigated the feasibility of combining infarct localization and cardiac modeling to personalize pathological LV for better assessment of heart conditions post-MI. Future studies built on this approach on clinical data are necessary, primarily to investigate the correlation between the personalized material

parameters and the real condition of the patient through several time points of CMR acquisitions, in order to predict the future condition of the patient's heart.

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