VIRTUAL HEART MODELS: MULTI-PHYSICS APPROACHES TO COMPUTATIONAL CARDIOLOGY

Reporting

Project Information

VHEART

Grant agreement ID: 294161

Status
Closed project

Start date
1 September 2011

End date
31 August 2015

Funded under
FP7-PEOPLE

Overall budget
€ 100 000

EU contribution
€ 100 000

Coordinated by
MIDDLE EAST TECHNICAL UNIVERSITY
Turkey

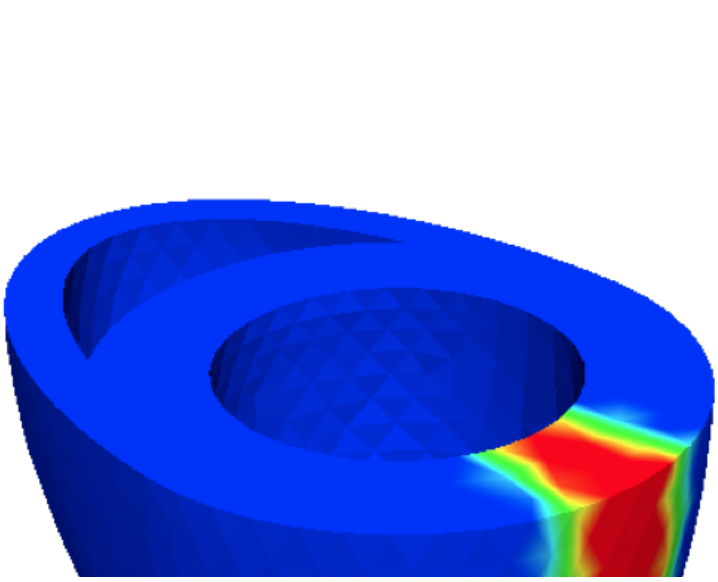
Final Report Summary - VHEART (VIRTUAL HEART MODELS: MULTI-PHYSICS APPROACHES TO COMPUTATIONAL CARDIOLOGY)

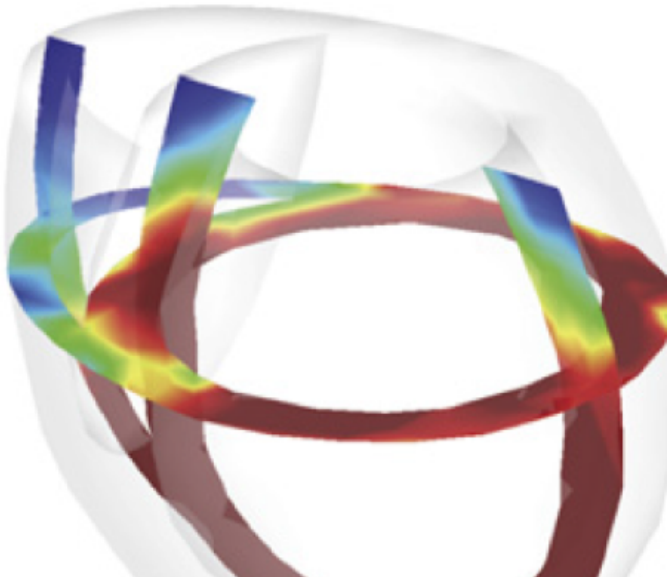
In the EU alone, heart disease causes over two million deaths each year. In spite of a broad spectrum of treatment techniques such as medication, surgery, and tissue-engineered therapies, heart disease remains to be one of the most frequent, disabling, and life-threatening diseases. More importantly, the rate of deaths due to cardiac disease is expected to rise in the near future. As opposed to the traditional trial-and-error based therapies, a systematic, personalized simulation-aided approach offers a great potential for understanding, diagnosing, and treating heart failure through the sound understanding of functional and structural changes in the infarcted tissue and the computational tools of multi-scale solid mechanics.

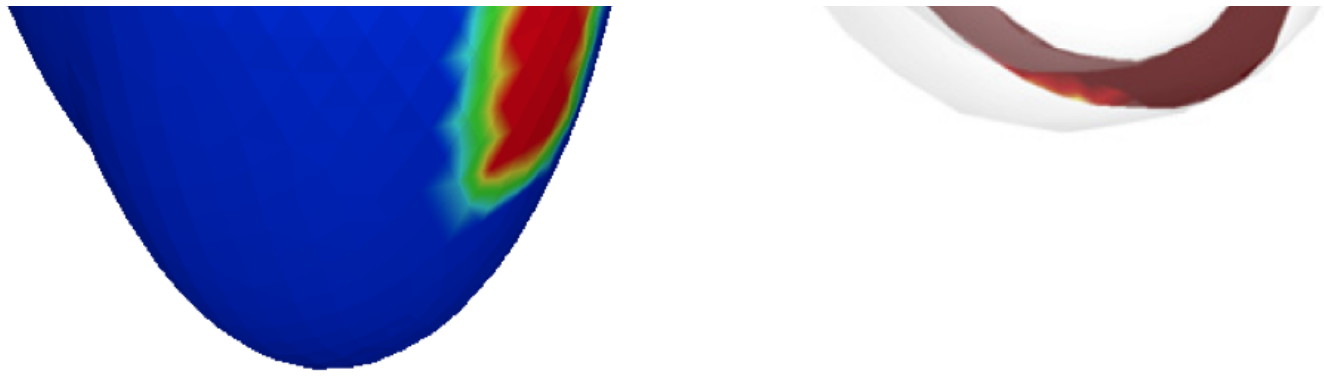
The overall goal of this interdisciplinary research project is to develop multi-scale continuum mechanics models supplemented by robust and efficient computational techniques to improve the understanding of

the complex bio-electro-mechanical underpinning mechanisms in cardiac function and diseases. To this end, we have developed a novel, monolithic, and unconditionally stable finite element algorithms for the mono- and bi-domain based approach to cardiac electrophysiology and electromechanics. Moreover, we have developed a coupled chemo-electro-mechanical model that allows us to predict how chemical, electrical, and mechanical fields interact across three biological scales during throughout a cardiac cycle. Pharmacological treatment of cardiac disease has advanced significantly over the past decades. Hence, the proposed algorithms and models has a great potential to open new avenues to patient specific therapy design by circumventing stability and convergence issues inherent to conventional staggered solution and to elucidation how the local biochemistry of an individual heart cell translates into global cardiac function. In addition, we have generalized the one-dimensional Hill model to the three-dimensional setting where the advantageous features of the active-stress and active-strain approaches are incorporated within a unified constitutive framework. The inherently anisotropic microstructure of cardiac tissue is accounted for in the active deformation tensor that evolves with the intracellular calcium transient. The proposed formulation is the generalization of the approaches that employ either additive stress decomposition or the split of the deformation. We anticipate our generalized Hill model to be broadly applicable to smooth muscle, skeletal muscle, and cardiac muscle and to provide sound and fundamental insight into dysregulated excitation-contraction coupling in various diseases such as gastrointestinal track disorders, vascular disorders, neuromuscular diseases, and heart disease. By using the models developed, we have started to investigate different types of heart disease related to the electrophysiology and electromechanics of the heart. For this purpose, we have considered infarction, eccentric and concentric hypertrophy as examples related to cardiac mechanics and the left bundle block and fibrillation as instances of cardiac electrophysiology. Our computational results favorably resemble the clinical findings based on pressure-volume curves and electrocardiograms.

With the help of this project the fellow has established his independent research group to a large extent, disseminated the research results as several papers and conference talks, and collaborated with the leading researchers both from the EU and the US. The Grant was extremely beneficial to the fellow for his research career development and his re-integration. The dissemination activities and the basic information about the project are presented on the personal webpage of the fellow at http://users.metu.edu.tr/sgoktepe/.







final1-illustrativepicture.png

Last update: 4 February 2016
Record number: 176627