Interactive 3D Human Heart Simulations on Segmented Human MRI Hearts

John P. Berman*, Flavio H. Fenton, Elizabeth M. Cherry, Tinen Iles, Paul A. Iaizzo, Abouzar Kaboudian

Georgia Institute of Technology, Atlanta, GA, USA

Aims: Understanding arrhythmic mechanisms in the heart and developing new strategies to control and terminate them using computer simulations requires realistic physiological cell models with anatomically accurate heart structures. Furthermore, it is necessary that the numerical simulations are fast enough to study and validate the model and structure parameters. Here, we present an interactive parallel approach for solving detailed cell dynamics in high-resolution human heart structures with a local PC's GPU.

Methods: *In vitro* human heart MRI scans from the Atlas of Human Cardiac Anatomy of the University of Minnesota were segmented and the atria and ventricles boundaries identified and separated. Other elements such as the His-Purkinje fiber activation sequence and rotational anisotropy were implemented through existing rule-based methods to accurately represent atrioventricular electrical connections. The Abubu.js library was used to create an interactive code to solve the OVVR human ventricular cell model and the FDA extension of this model in the human MRI heart structures.

Results: We are able to perform simulations in the ventricular and atrial structures independently and as a whole heart. Interactivity of the code in real time allows the initiation of reentrant waves and investigation of their dynamics in the 3D structures as a function of parameter values. All OVVR model parameters are accessible during the simulation for sensitivity analysis as well as to study wave dynamics. Most notable is the propagation of waves through the trabeculae in the ventricles and the pectinate muscles in the atria affecting the complexity of arrhythmia dynamics.

Conclusion: Interactive simulations of a physiological cell model in a detailed anatomical human heart reveals propagation of waves through the fine structures of the trabeculae and pectinate muscle that can perpetuate arrhythmias, thereby giving new insights into effects that may need to be considered when planning ablations and other defibrillation methods.

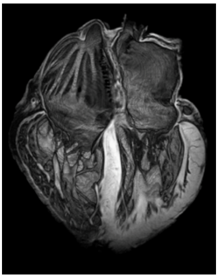

Figure 1: Cross section of an ex-vivo human heart MRI scan, showing detailed pectinate muscles in the atria and trabeculae in the ventricles.