SUBJECT SPECIFIC, IMAGE BASED ANALYSIS AND MODELING IN PATIENTS WITH ATRIAL FIBRILLATION FROM MRI

Rob S. MacLeod, Josh Blauer, Eugene Kholmovski, Ravi Ranjan, Nassir Marrouche (SCI Institute, CARMA Center, University of Utah); Natalia Trayanova and Kathleen McDowell (Johns Hopkins University); and Gernot Plank (University of Graz)

Atrial fibrillation (AF), a very common cardiac arrhythmia, has recently emerged as a new interdisciplinary epicenter of clinical, engineering, and basic science research. This emergence is fueled by new results from experiments, animal models of the disease, and multimodal measurements in patients, catalyzed by rapid developments in interventional approaches to treatment. Our understanding of the disease is growing but still inadequate to provide satisfactory patient care and so there is enormous opportunity for a range of research approaches. Some attributes of the disease also make it a simultaneously compelling, accessible, and challenging target for inquiry; AF emerges only as a result of long term changes in tissue substrate, is triggered by remote ectopic activity, involves one or more mechanisms of cardiac arrhythmias, has a variable time course in individuals, and is both damaging to immediate quality of life and a major risk for secondary disease.

The goal of this presentation will be to provide an overview of the disease and its putative mechanisms, to outline the range of inquiry possible and necessary, and then to emphasize the image based techniques that characterize the CARMA approach to understanding and treating AF. Imaging across many scales is central to all aspects of understanding AF as it allows one to capture the structure changes that appear to be the essential elements of the damaged substrate. Histological imaging reveals the disruption of normal close proximity of atrial cells that creates delayed conduction and conditions for arrhythmias. Confocal imaging offers three-dimensional access to myocardial structure and further expands our ability to identify collagen septa, myofibroblasts, and apoptotic cells and to create realistic models of the heterogeneous tissue. MRI offers an even larger scale view of the atria and combined with late gadolinium can document the distribution of clinical fibrosis that we have shown to predict success of clinical interventions to treat AF.

While images provide qualitative information through direct observation, quantitative analysis and interpretation and especially modeling and simulation require algorithms and software. We have developed a complete suite of open source software tools that support rendering of three-dimensional image data, extracting the tissue boundaries and tissue heterogeneities through semi-automated segmentation, and generating high quality meshes for visualization and modeling of cardiac electrical activity. The resulting pipeline supports clinical evaluation of the extent and distribution of atrial fibrosis and scar, carried out daily by the CARMA team from patient MRI scans, and research studies from animal models and experiments that seek to reveal underlying mechanisms through measurements and simulation. In this presentation we will summarize these activities and results that illustrate the utility of such a multiscale, image base approach.