Cardiac fiber orientation in goat measured with Diffusion Tensor Imaging

T6.33

Bidomain Modeling of Reentrant Rotating Waves

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Rotating wave reentry has been recognized as one of the possible major episodes associated with cardiac arrhythmias, and various modeling studies have been performed to understand the underlying mechanisms. Most of these studies, however, are limited to the use of the simplified monodomain model that does not accurately represent the different anisotropy ratios of the intracellular and interstitial conductivities. Here, we describe an examination of the reentrant rotating waves in a twodimensional rectangular domain using the full bidomain model. Realistic nonlinear formulations, e.g., Beeler-Reuter and Luo-Rudy models are used to represent the membrane ionic currents. Spatial discretization is achieved with the finite difference method, and both the explicit and implicit-explicit techniques are used to advance the solution in time. An S1-S2 stimulation protocol is used to elicit spiral waves in both monodomain and bidomain models. Properties of the waves in the two models are compared for a range of conductivity values.

T6.34

Power-Law Relationship of Heart Rate Variability as a Predictor of the Need for Pacemakers in Patients with Atrial Fibrillation.

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Power law regression parameters of RR-interval variability have been shown to be excellent predictors of death of any cause especially arrhythmic death, and to predict this outcome better than the traditional power spectral bands. To investigate whether or not power law regression parameters can also be useful markers in deciding if a patient suffering from atrial fibrillation would need a pacemaker, spectral analysis of 24hour RR-intervals was computed. We compared two groups of patients with atrial fibrillation, one needing pacemakers (12 patients) and the other without the need of pacemakers (7 patients). A fast Fourier transform was used to estimate the power spectrum densities of hear rate variability (HRV) of 24-hour Holter recordings. The power-law relationship of HRV was calculated from the frequency range of 10-4 to 10-2. For those patients with and without the need of pacemakers, the mean slope was -0.84 and -0.98, respectively ($P < 0.05$). Interestingly, the negative slope value of -0.98 for patients without the need of pacemakers, is similar to the reported slope of -1 for healthy subjects. This finding suggests that attenuation of the downward negative slope of the power law relationship is a marker for predicting the need of pacemakers in patients.

T6.35

iCell: An Interactive Cell Modeling Tool for Electrophysiology

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An internet site, iCell, was developed as an interactive cell modeling software for electrophysiology and is located at http://ssd1.utmem.edu/complib/. The site acts as a computational library to provide simulation data for bioelectric activity at cellular level, and consists of Java applets representing models of various cardiac cells and neurons, and a glossary. The cell models in iCell are grouped into versions and cardiac or neuron "modelboxes," and allow the user to go through menu options to choose simulation protocols, change model parameters, run and view simulations. iCell is mainly used as a simulation-based learning, teaching and collaboration environment for electrophysiology. It was utilized as a teaching and learning tool for various courses, which had lectures on computational representations of cell membrane behaviors, at the Joint Biomedical Engineering Program of University of Memphis and University of Tennessee. This modeling tool was also used as a collaboration site among our colleagues interested in simulations of cell membrane activities. The platform-independent software, iCell, provides us with an interactive and user-friendly teaching and learning tool, and also a collaboration environment for electrophysiology to be shared over the Internet. (This research is being funded by the Whitaker Foundation.)

6.2.1 Cardiovascular Imaging for Function and Therapy

T6.36

Assesing Ventricular Mechanics with Computer Aided Speckle Interferometry

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A new technique in cardiac surgery is the off-pump coronary artery bypass (OPCAB) procedure. This procedure does not require the use of the cardiopulmonary bypass pump, it does require a short period of regional myocardial ischemia. It is unknown how well this ischemia will be tolerated until myocardial damage becomes clinically apparent. Therefore, we are developing a technique to determine myocardial mechanics with high spatial resolution, as a real time marker of cardiac ischemia.

Computer Aided Speckle Interferometry (CASI) is a novel technique that can determine 2D-epicardial deformation with high spatial resolution. CASI uses Fourier transforms to correlate the light intensity distribution between "subimages" in consecutive images and determine the displacement. We have shown this technique to correlate well with sonomicrometry.

With the use of a high-speed camera we have used CASI to determine wholefield (4 cm2) regional deformations with a spatial resolution of 0.01 mm2 in mammalian hearts. In non-beating ischemic hearts, we have been able to determine changes in the angle of principle strain as compared to perfused hearts. This novel technique determines regional myocardial function, which will be useful in elucidating the consequences of ischemia in the setting of an OPCAB procedure.

T6.37

Cardiac fiber orientation in goat measured with Diffusion Tensor Imaging.

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In numerical studies it has been shown that the distribution of fiber stress and strain is very sensitive to fiber orientation. Furthermore, within the anatomical range a fiber distribution can be found for which stress and strain throughout the cardiac wall are homogeneous during ejection (1). We therefore hypothesize that fiber reorientation could be a local adaptive mechanism by which the strain distribution across the cardiac wall is homogenized. To test this hypothesis we measured fiber orientation in normal goat hearts and in goat hearts in which the mechanical load was locally disturbed by induction of an infarction. Diffusion Tensor Imaging was used to measure fiber orientation in voxels of $0.4\times0.4\times3.0$ mm3 . The figures below show the out-of plane component of fiber orientation in an equatorial short-axis cross-section for the normal heart (left) and the 10 weeks infarcted heart (right). Normal fiber orientation was characterized by a circumferential orientation of midwall fibers. Preliminary results of measurements after 10 weeks infarction reveal a disturbance of this characteristic pattern.

1. Rijcken et al. (1999) Annals of biomedical engineering, 27:289-297.

T6.38

Myocardial Repair with ECM Scaffolds

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The extracellular matrix derived from the urinary bladder submucosa (UBS) and small intestinal submucosa (SIS) has been used as an inductive resorbable scaffold for various tissue engineering applications in both animals and humans. Angiogenesis, neo-ECM deposition, and host cellular differentiation have been characteristic of this ECM-assisted repair. We report the use of UBS and SIS as a scaffold for the repair of the right ventricular free wall and right ventricular outflow tract in a porcine animal model. Surgically-created, full-thickness defects in the right ventricle, measuring approximately 1.5 cm in diameter, were repaired with a sheet of either UBS or SIS measuring approximately 80 mm in thickness. Animals were sacrificed at periods of time ranging from 6 weeks to 5 months post surgery. There was replacement of the scaffolds by viable and contractile myocardium intermixed with bands of collagenous connective tissue. The thickness of the newly formed myocardium approximated that of the adjacent native myocardium by 3 months. The neo-endocardium was morphologically normal and covered by normal endothelial cells. In vitro contractility tests showed that the remodeled tissue could generate contractile forces up to 70% of that produced by native myocardium.

In summary, the use of an acellular scaffold derived from extracellular matrix holds promise for repair of damaged or missing myocardium.