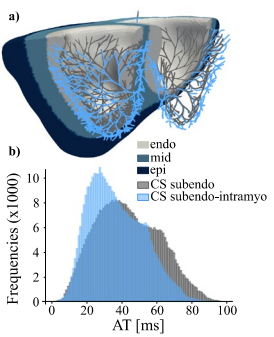
Ventricular Conduction System Modeling for Electrophysiological Simulation of the Porcine Heart

Ricardo M. Rosales*, Konstantinos A. Mountris, Manuel Doblaré, Esther Pueyo

University of Zaragoza, IIS Aragon & CIBER-BBN, Zaragoza, Spain

The cardiac conduction system (CS) determines the cardiac depolarization sequence, which triggers mechanical contraction to pump blood throughout the body. CS descriptions have been incorporated into computational models of the heart to assess complex cardiac conditions and design therapeutic actions at an affordable cost. This work proposes an anatomically-realistic, semiautomatic generation of porcine CS representations to accurately reproduce depolarization patterns in computational biventricular models.

Two personalized ventricular geometries and their fiber fields were reconstructed from diffusion-weighted magnetic resonance images. Transmural heterogeneities were determined by solving a diffusion problem along the wall thickness. Manually-determined anatomic landmarks with geodesic paths and a fractal tree algorithm were employed for CS construction. We defined two CS distributions, one restricted to the subendocardium and another one by performing a subendo-to-intramyocardium projection based on histological porcine evaluations. Simulations were conducted by solving the monodomain model with the finite element method. Activation times (ATs) and depolarization patterns (DPs) were computed for the two CS distributions in the two geometries and results were compared with experimental data.



Personalized biventricular model (a) and histograms of ventricular ATs (b) for subendocardial (grey) and subendo-intramyocardial (light blue) CS distributions.

Ventricular activation was faster for the subendo-intramyocardial CS than for the subendocardial one. Specifically, with the subendo-intramyocardial CS, 50% of ventricular tissue was activated 3 ms and 8 ms earlier than for the subendocardial CS for the first (thinner ventricular wall) and second (thicker ventricular wall) geometries, respectively. Ventricular DPs were in good agreement with experimental results for both CS distributions, with maximal AT being better reproduced by the subendo-intramyocardial CS distribution.

In conclusion, we have defined biophysically-detailed models of the porcine ventricles with biomimetic CS representations and shown their ability to represent experimental depolarization properties.