A 3D electromechanical model of the human atria: a realistic framework for the study of Atrial Fibrillation

Eva Casoni(*), Constantine Butakoff, Jazmin Aguado-Sierra, Violeta Puche, Mariano Vazquez, Beatriz Trenor, Javier Saiz

ELEM Biotech SL, Barcelona, Spain

Aims Atrial fibrillation (AF) is the most common cardiac arrhythmia and it is mainly sustained by rapid ectopic activity, which affects the electromechanical dynamics of the cardiac tissue. The objective of the present work is to develop a highly detailed 3D electromechanical model of the human atria in order to assess how atrial fibrillation-induced electrical remodelling affects atrial mechanical contraction. We aim to quantify the regional stress and their potential influence on AF risk.

Methods The atrial 3D anatomical model included fibre orientation measured from histological sections of a human anatomy. The mathematical model of human cardiac atrial myocytes proposed by Courtemanche was used to solve the electrophysiology using a monodomain approximation. Furthermore, stretch-activated channels were integrated to the Courtemanche atrial model. Regional tissue heterogeneities were incorporated in the model both at the cell level by modifying ionic channel conductances (9 celltype regions), and at the tissue level to assign regionally heterogenous anisotropic and diffusion properties to reproduce the normal atrial conduction. The model is coupled to the tissue mechanics, with the excitation-contraction model proposed by Land et al. The solid mechanics tissue constitutive model is the one proposed by Holzapfel and Ogden. AF electrical remodelling is introduced and the simulations are performed under different scenarios, including normal and AF sinus rhythm, and AF ectopic pulses.

Results Electro-mechanic simulations produced a shortening of the action potential and a reduced concentration of calcium for AF simulations as compare to normal conditions, resulting also in a reduced active force. A detailed distribution of the principal strains and stresses were also obtained and analyzed within the different AF scenarios.

Conclusions The detailed model of electromechanical coupling in the 3D human atria provides new insights into the mechanistic links between atrial electrophysiology and tissue mechanics during normal activation and while sustaining AF. This study provides a computational framework for investigating the role of stretch-activated channels into the AF pathophysiology and explore potential drug candidates to treat AF.