Cardiac Sensitivities to Biomechanical Changes in a Chronic Alcoholic Heart: A Case Study Using 3-Dimensional Electro-Mechanical Heart Modelling

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This Chronic excessive alcohol consumption leads to impaired cardiac function. This is due to a combination of changes to anatomy, material properties and pre/after load. Identifying the mechanisms that underpin alcohol induced impaired cardiac function could improve diagnosis, patient selection, and therapy monitoring. We propose the use of a multi-scale physics and physiology informed 3D electro-mechanical cardiac simulator to integrate patient data and determine which biomechanical factors have the greatest impact on whole heart function. Representative patient specific four chamber anatomical models were constructed of a control and a chronic excessive alcohol consumption patient. The heart model simulated cellular, tissue and organ scale electrophysiology and mechanics coupled to a closed loop cardiovascular system model. The relative importance of biomechanical parameters representing myocardial stiffness, ventricular pressures, and vascular resistance were evaluated. A database of 100 simulations were performed in each case using a Latin Hypercube (LH) sampling method. Gaussian Process Emulators (GPE) were trained to each simulation database for ejection fraction and maximum pressure in left and right ventricles and left ventricular (LV) end-diastolic volume outputs. The GPE was used to perform a sensitivity analysis.

We found that the LV end-diastolic pressure was the most influential parameter affecting the outputs in both models. The LV stiffness had a considerable impact compared to the stiffness of atria on the ejection fraction of the right ventricle (RV) in the alcoholic heart model. Furthermore, systemic resistance showed greater influence than pulmonary resistance, particularly in the alcoholic heart model.