Investigating the Influence of Parameters on Electrogram Morphology Using Gaussian Process Emulators

Manisha Sahota*, Fernando O Campos, Shuang Qian, John Whitaker, Steven E Williams, Matthijs Cluitmans, Steven A Niederer, Martin J Bishop

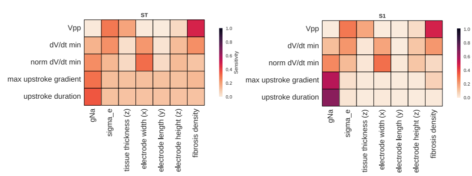
King's College London, London, UK

Background: Intracardiac electrograms (EGMs) are commonly used to assess cardiac arrhythmias to gain information about structural alterations of underlying tissue. Computational models offer a systematic approach to study how parameters such as myocardial tissue thickness influence EGM morphology. However, global sensitivity analyses are challenging to perform due to the high computational cost of such multi-parametric and nonlinear models.

Objective: To evaluate the impact of myocardial tissue thickness, electrode size and conduction slowing on the amplitude and minimum temporal derivative of the unipolar EGM voltage (dV/dt_{min}), identifying key parameters that influence the EGM morphology.

Methods: A realistic computational model of healthy myocardial tissue and bath was generated with a highly conductive electrode on the endocardial surface. Bidomain simulations were performed with a planar wavefront perpendicular to the electrode. The impact of myocardial tissue thickness, electrode size and conduction slowing via altering fibrosis density, sodium channel conductance (g_{Na}) and intracellular (σ_i) and extracellular (σ_e) conductivities on EGM and action potential (AP) morphology were investigated by training Gaussian process emulators (GPEs) to perform a Sobol variance-based global sensitivity analysis (GSA).

Results: The trained emulators achieved a median R^2 test score of 0.91 and ISE of 97.5. GSA revealed a strong influence of fibrosis density and σ_i/σ_e on EGM amplitude, with reduced fibrosis density and increased σ_i/σ_e generating EGMs with larger amplitudes. Both σ_i/σ_e and g_{Na} exerted similar effects on dV/dt_{min}, though g_{Na} more significantly influenced AP morphology, as expected. Myocardial tissue thickness heterogeneity most greatly influenced the EGM amplitude but had minimal association with dV/dt_{min}. Electrode width had the greatest impact on dV/dt_{min}, though electrode length and height had negligible influence.



GSA heatmaps of total order (ST) and first order (S1) Sobol indices.

Conclusion: This study demonstrates the efficacy of GPEs as a robust approach to perform a computationally efficient GSA, gaining deeper insights into the link between cell and tissue properties and intracardiac EGMs.