Uncertainty Quantification of Cardiac Position on Deep Graph Network ECGI

Xiajun Jiang, Jess Tate, Jake Bergquist, Akil Narayan, Rob MacLeod, Linwei Wang

Traditional ECGI incorporates numerical solutions to three-dimensional bioelectric field simulations to estimate cardiac activity from recorded surface potentials. Previously, we introduced a graph-based neural network to compute ECGI solutions in an effort to improve accuracy. However, geometric uncertainty has not been addressed in these network-based simulations. We know from previous work that cardiac position can be difficult to recreate in silico and can impact torso simulations and ECGI. In this study, we applied uncertainty quantification with polynomial chaos emulators (PCE) to the graph-based neural network to estimate uncertainty due to cardiac positions.

To estimate the effect of geometric variation from common motions, change in cardiac position was parameterized by three rotations and an inferior-superior translation. Changes in torso geometry were applied as an anterior-posterior scaling. The graph-based neural network was trained using multiple recorded beats and the nominal geometry obtained from a torso tank experiment including tank and pericardial sock electrodes. Then, we ran the model with geometries sampled from the parameter space using weighted Fekete sampling. Statistics of the output distribution were estimated from the model solutions using PCE.

The uncertain heart position and torso size showed high levels of variability in cardiac potentials predicted by the trained graph-based network. The standard deviation of the predicted pericardial potentials scaled with signal amplitude, yet was often comparable to peak-to-peak amplitude of the electrograms. Why the uncertainty varied over time, with the maximum variability occurring near the peak of the QRS wave, uncertainty was evenly distributed over the surface of the model. Derived metrics, such as the local activation times, showed similarly high uncertainty.

This work highlights the sensitivity of the trained graph-based neural network to heart position and torso size and helps us direct development of similar models to account of possible variability.

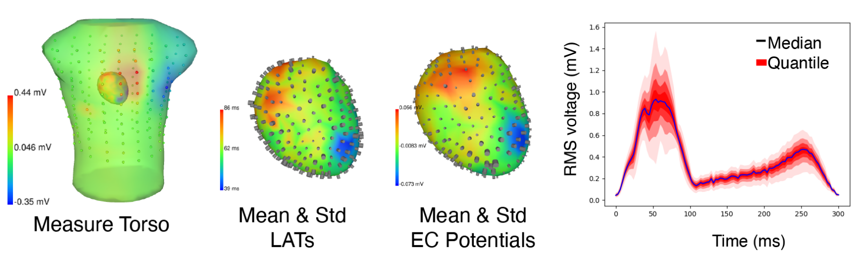

Figure 1: Variability of the trained graph-based neural network to uncertain heart position and torso size. From left to right: measured torso potentials, mean (colormap) and standard deviation (cylinder size) of the local activation times, mean and standard deviation of the pericardial potentials, and the median and eight quantile zones of the RMS voltage of the pericardial potentials.