Intracardiac electrical imaging using the 12-lead ECG: a machine learning approach using synthetic data

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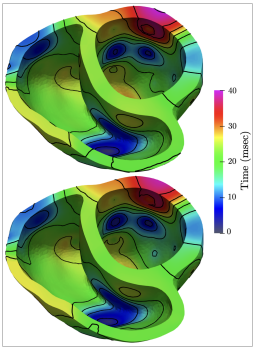
Aims: Current state of the art techniques for non-invasive imaging of cardiac electrical phenomena require voltage recordings from dozens of different torso locations and anatomical models built from expensive medical diagnostic imaging procedures. This study aimed to assess if recent machine learning advances could alternatively reconstruct ventricular transmural activation maps and full transmembrane voltage evolutions at clinically relevant resolutions using only the standard 12-lead electrocardiogram (ECG) as input.

Methods: A computational study was conducted to generate a dataset of over 16000 simulations of cardiac electrophysiology at high spatiotemporal resolutions (200 microns and 5 microseconds). The dataset, which is made publicly available for further cardiac machine learning research, was built using real cardiac biventricular geometries and clinical endocardial activation patterns under different physiological and pathophysiological conditions. A novel neural network (NN) architecture using 1D convolutional kernels was developed to exploit both spatial and temporal correlations present in the ECG. This joint spatiotemporal processing of the signal is missing in classical inverse problem approaches and was critical for high quality reconstructions.



High resolution simulation (top) and NN reconstruction (bottom) of activation map

Results: Analysis over a validation set showed average errors in activation map reconstruction below 1.7 msec over 75 intracardiac locations. Furthermore, phenotypical patterns of activation and the morphology of the activation potential were correctly reconstructed, including the action potential duration and the complete dynamical evolution of the depolarization and repolarization phases of the cardiac cycle.

Conclusions: Reconstruction of non-invasive electrical maps from just a 12-lead ECG is possible given enough data. The NN offers opportunities to stratify patients non-invasively, both retrospectively and prospectively, using metrics otherwise only available through invasive clinical procedures.