Combining Biophysical Modeling and Machine Learning to predict location of atrial Ectopic Triggers

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Motivation: The localization of ectopic triggers in the atria requires that an electrophysiologist maps the electrical activity in the endocardium to infer, based on his experience, the area where tissue should be ablated to eliminate an arrhythmia. When triggers are located in non-standard regions, or only generate a few ectopic activations, it can be complex and time consuming its localization. The development of non-invasive techniques based on surface-ECG data that can assist electrophysiologist intraoperatively could improve radio-frequency ablation success rates.

Aims: This study aims to show a methodology to estimate the location of ectopic foci by means of a machine learning system trained with multi-electrode ECG data generated by means of a detailed biophysical model of the atria and torso. The use of biophysical simulations allows the definition of hundreds of scenarios that are posteriorly run in a high-performance computer and do not require any further computation in the clinical environment. The machine learning system, based on the simulated data, is able to identify the region in which the ectopic focus is located.

Methods: The biophysical simulations were performed in 3D models of the atria that considered the specific fibre orientation at 21 different regions, and tissue and cellular heterogeneity at 10 regions. The ionic cellular model used was Courtemanche for the healthy tissue and MacCannell for fibrotic tissue. A total of 500 simulations of 200ms in 26 configurations of the atria (i.e., different distributions of fibrosis) were carried out (Figure 1, left panel), and propagated to the torso surface to obtain the body surface potential maps (BSPM). BSPM were clustered and labelled using a hierarchical clustering method (Figure 1, central panel), and a support vector machine was trained with BSPMs and labels. Finally, a cross-validation was performed to analyse the accuracy of the method to predict the label of a BSPM, which is related to the location of the corresponding ectopic focus on the atria (Figure 1, right panel). The whole procedure was completed for input BSPMs with varying number of electrodes.

Results: Focal activity was triggered from 20 different atrial locations, and BSPMs were collected using a number of electrodes that ranged from 2 to 256. The ectopic foci were grouped in the atria into regions that vary between K=2 and K=10 regions. The results from the cross-validation showed that in general 32 electrodes were enough to predict the region of an ectopic focus with an accuracy of 90% in patient without presence of fibrosis or with a level of fibrosis of around 5%. As fibrosis increased, the system required at least 64 electrodes to reach the same accuracy. However, in cases with fibrosis over 15% the labels assigned to the atrial regions overlapped, which blurred the association between BSPM and specific atrial regions, hampering its utility.

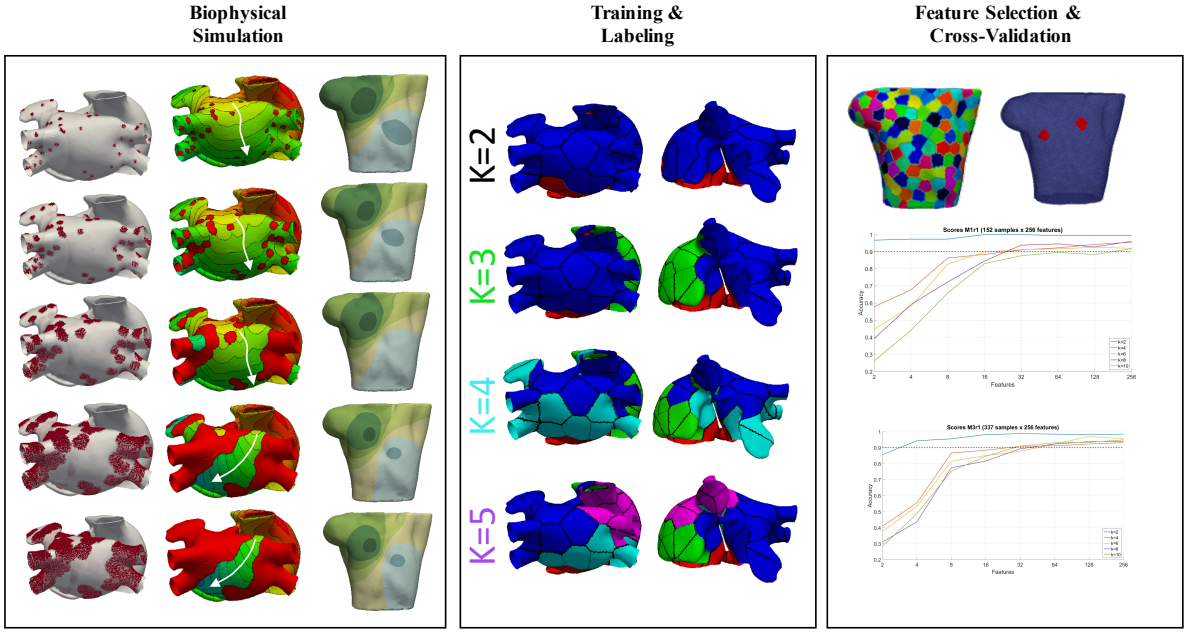

Figure 1: Left panel shows five atrial models including fibrosis (red areas), the local activation times in the atria, and the corresponding BSPM in the torso for a given ectopic focus location. Central panel shows how are the ectopic foci clustered in atrial regions (as a function of K chosen). Right panel shows the location of the electrodes on the BSPM (max. 256) and the results for the cross-validation as a function of the number of electrodes and ectopic clusters.