Machine Learning to Find Areas of Rotors Sustaining Atrial Fibrillation from the ECG

Giorgio Luongo, Luca Azzolin, Massimo W Rivolta, Tiago P Almeida, Juan Pablo Martinez, Diogo C Soriano, Olaf Dössel, Roberto Sassi, Pablo Laguna, Axel Loewe

Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

Aims: Atrial fibrillation (AF) is the most frequent irregular heart rhythm due to disorganized atrial electrical activity, often sustained by rotational drivers called rotors. The non-invasive identification of AF driver locations can lead to the best personalized ablation strategy, suggesting pulmonary vein isolation (PVI) in case the driver is located on the pulmonary veins (PVs) or more complex extra-PV ablation procedures in case the driver is on other atrial regions. Using a Machine Learning approach, we sought to characterize and discriminate the simulated single stable rotors (1R) location: PVs, left atrium (LA) excluding the PVs, and right atrium (RA), utilizing solely non-invasive signals (i.e., the 12-lead ECG).

Methods: 1R episodes sustaining AF were simulated using the phase singularity distribution method on a volumetric atrial model and the ECGs were forward calculated in 8 torso models, resulting in 440 sets of 12-lead ECG signals (40, 112, and 288 ECGs with 1R located in the PVs, other LA areas, and RA, respectively). 128 features were extracted from the signals, such as Hjort descriptors, recurrence quantification analysis (RQA), and principal component analysis. A greedy forward algorithm was implemented to select the best feature set which was fed to a decision tree classifier with hold-out cross-validation technique.

Results: All features showed significant discriminatory power, with particular emphasis on the RQA parameters (up to 80.9% accuracy with single feature classification). The decision tree classifier achieved 89.4% test accuracy with 18 selected features on simulated data, with sensitivities of 93.0%, 82.4%, and 83.3% for RA, LA, and PV classes, respectively.

Test-Set Confusion Matrix

		True class		
		RA	LA	PV
Predicted class	RA	40	2	0
	LA	3	14	1
	PV	0	1	5

Conclusion: Machine learning approaches could potentially identify the location of 1R sustaining AF using the 12-lead ECG. This non-invasive method might guide ablation procedures, highlighting atrial regions that may be important in the AF perpetuation, and hence targets for ablation, prior to invasive electrophysiologic mapping system.