Insights from Explainable Machine Learning on Biatrial Arrhythmia Vulnerability Assessment

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Background: Despite recent advancements in comprehending atrial fibrillation pathophysiology, identifying individuals prone to developing arrhythmia remains difficult in clinical practice. Patient-specific computer models of the atria are a promising tool for assessing arrhythmia vulnerability in silico, yet these models are computationally expensive. Modelling and simulation combined with machine learning could provide a faster alternative compatible with clinical timeframes.

Methods: We created 24 personalized biatrial computer models using LGE-MRI data. Arrhythmia vulnerability was assessed with a virtual S1S2 pacing protocol. Clinical and fibrosis features associated with arrhythmia propensity were extracted and used to train a random forest classifier to identify points inducing reentry. Features were assessed globally, and fibrotic features were further assessed locally. SHAP explainability elucidated feature interactions and their impact on predicting arrhythmia vulnerability.

Results: The pacing protocol simulation duration was 765 ± 256.2 min per biatrial model. The machine learning model required 0.6 s to train and 0.01 s for validation. A total of 1079 reentries were induced. The random forest classifier achieved an area under the receiver operating characteristic curve of 0.73 ± 0.04. Conduction velocity and fibrosis density in 10 mm proximity were the features showing the highest impact on point inducibility prediction. Sphericity and RA volume showed minimal impact on the prediction.

Conclusions: The presented classifier may be a fast alternative for assessing arrhythmia vulnerability in silico without expensive computations of virtual pacing protocols, thus aiding the transition to clinical applications.

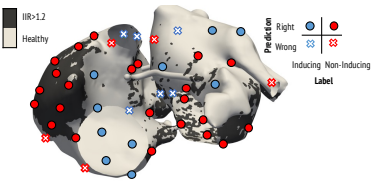

Figure 1. Analysis of model prediction, point inducibility, and fibrosis distribution. Color represents inducibility, where red denotes non-inducing and blue indicating inducing points. Circles denote correct predictions, while crosses denote incorrect predictions. Areas of high intensity are shown in gray.