Reducing Noise in Atrial Fibrillation Electrograms Using Autoencoder Neural Networks

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Introduction: Mapping Atrial Fibrillation (AF) is complicated as electrograms can show activations that are not local but arise from far field, noise or other sources. These spurious signals occur despite modern filtering techniques to tackle AC noise or cross-talk from other chambers and pacing. Template matching requires libraries that are rarely available, beat averaging obscures beat-to-beat variation and is suboptimal for dynamically changing signals, smoothing blurs high-frequencies and loses transient data. We hypothesise that Neural Networks (NN) based on an encoder-decoder architecture can learn physiological features of signals, and reconstruct them from a latent feature space without noise even when training in a different cohort of related signals.

Methods: The figure outlines our methods. We designed an autoencoder NN and tuned it using well characterised electrophysiological signals with verifiable shapes – and thus selected monophasic action potentials (MAPs). The NN was used to reconstruct, denoise and classify ventricular and atrial MAPs, evaluating the reconstruction with a novel similarity parameter based on an inverse cubic loss function and Pearson Correlation (PC). We trained on 5706 ventricular MAPs from 42 patients. For transfer learning, we fine-tuned on a set of 641 atrial MAPs in 21 patients.

Results: The autoencoder NN reconstructed ventricular MAPs with a PC = 0.99±0.01 (**A**). Atrial MAP reconstruction improved from PC = 0.87±0.11 to PC = 0.99±0.01 after fine-tuning. Key physiological features such as upstroke and MAP shape were learned in the latent space, enabling the NN to denoise pacing artifact (**B-C**), truncation of MAP downstroke (**H-I**), high frequency noise (**F-G**), or ventricular artifacts (**D-E**) without manual annotation.

Conclusions: Autoencoder NN is a novel and powerful tool that can automatically eliminate diverse types of noise in single beats by learning essential physiological signal features, even when trained in signals from more available datasets in a different heart chamber. This approach may have far-reaching applications for mapping and ablation, and can be used to denoise other electrophysiologic signals of higher interest without manual annotation.