Weakly Supervised P-wave Segmentation in Pathological ECG Signals Using Deep Multiple-Instance Learning

Background: Obtaining training labels for ECG segmentation tasks relies on manual labeling of individual waves. This is usually time-consuming and lacks reliability in complicated rhythms. To alleviate this issue, we developed an automated pipeline for labelling a part of atrial wave in pathological ECGs using intracardiac electrograms as a reference. The cost of using this label source is incomplete information about overall duration, which we aim to address in this work.

Methods: We adopted a 1D fully-convolutional feature pyramid network (FPN) based on modified ResNet as our backbone architecture. P-wave detection was performed using fixed-size regions of interest (ROI) at different scales of extracted features. A bag label was assigned to each ROI according to a multiple-instance learning paradigm. ROI instance probability distribution vectors were aggregated by a semi-learnable pooling layer consisting of a multilayer perceptron followed by max-pooling. We trained and validated our model on an internal database containing 3265 short-term ECGs recorded in 708 patients (41.7 % women, median age 36.6 years) with various arrhythmias including premature beats, supraventricular tachycardias (1036 cases) and atrial fibrillation (458 cases).

Results: We achieved an overall validation Dice score of 0.811 for MIL aggregated probabilities. By thresholding normalized activation maps, we reached a sensitivity and predictive value of 0.63 and 0.69 for P-wave onset and 0.64 and 0.66 for P-wave offset on the validation subset. Most of the misclassified segments occurred during arrhythmias when the P-wave was superimposed on the QRS complex.

Conclusion: Our method successfully localized most of the P-waves occurring within ST and TQ segments during various pathological scenarios and differentiated well between atrial fibrillation and other rhythms. The framework showed promising performance in embedding the P-wave vector representation into a deep model with the possibility of transfer to other related tasks such as arrhythmia classification.

Example of P-wave probability map (blue) predicted by DNN model during multiple premature beats. CS – coronary sinus electrogram; solid vertical line – reference onset; dotted vertical line – reference offset.