Interpretable Deep Learning for Prehospital STEMI Detection from 12-Lead ECG

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Accurate and rapid detection of ST-elevation myocardial infarction (STEMI) in prehospital settings is essential for timely triage and initiation of primary percutaneous coronary intervention (PCI). However, variability in ECG morphology and noise in real-world environments make automated detection challenging. This study aimed to develop an end-to-end deep learning model for prehospital STEMI detection from 12-lead ECGs and to provide interpretable insights using Grad-CAM.

An end-to-end Multi-Scale Hybrid Transformer (MS-Hybrid Transformer) was developed to capture both local morphological features and long-range temporal dependencies. The model was trained using 10-second 12-lead ECG recordings from hospital-acquired data at Long Beach Medical Center (259 STEMI, 571 No-STEMI). Data augmentation using RandAugment, including time shifting, scaling, baseline wander, random point dropout, and Gaussian noise, was applied to improve generalization. Model development was performed using 10-fold cross-validation, and weights from 10 training loops were ensembled for final evaluation.

The model was externally tested on a prehospital dataset collected from a regional STEMI system of care at Carolinas HealthCare System (147 STEMI, 341 No-STEMI). The proposed model achieved a sensitivity of 0.76, specificity of 0.83, F1-score of 0.70, and accuracy of 0.81. Grad-CAM was applied to generate visual explanations, consistently highlighting clinically relevant regions associated with ST-segment and T-wave elevation across multiple leads (red: higher importance; blue: lower importance). Beat-level aggregation further enhanced interpretability by emphasizing stable diagnostic patterns.

This end-to-end MS-Hybrid Transformer enables accurate and interpretable detection of prehospital STEMI from 12-lead ECG signals. The integration of Grad-CAM provides clinically meaningful explanations aligned with established diagnostic criteria, supporting improved diagnostic confidence and clinical decision-making.

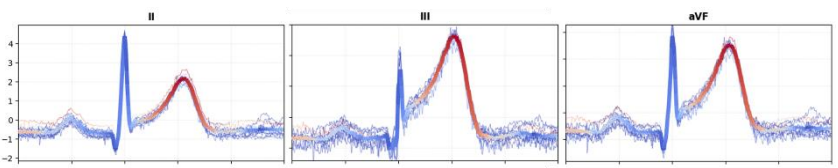

Figure 1. Beat-averaged Grad-CAM visualization for a representative prehospital STEMI case.