Machine Learning Estimation of Myocardial Ischemia Severity Using Body Surface ECG

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Introduction: Machine learning (ML) has emerged as a powerful method to improve the diagnosis of cardiovascular diseases through analysis of easily recordable body surface ECG data. Such ML tools can even detect abnormalities that are unavailable to traditional ECG analysis (e.g., ejection fraction). An outstanding clinical problem is the rapid and early detection and risk stratification of patients experiencing myocardial ischemia. Current, clinical diagnosis of myocardial ischemia from 12-lead ECGs can be non-specific and lacks precise information about the size and severity of ischemic regions in the heart, limiting the use of ECG-based risk stratification tools. Electrocardiographic imaging techniques may be able to address this challenge, however, such approaches add cumbersome and expensive imaging and modeling requirements which make them less suitable for clinical implementation.

Methods: We developed an ML tool to predict the size of ischemic regions within the heart using body surface ECG signals. Our dataset consisted of body surface ECGs and ischemic tissue volumes measured from 5 replicates of a large animal model during repeated episodes of graded ischemic stress. Ischemic tissue volume was measured by interpolating ST potential values recorded from intramural needle electrodes into the myocardial volume, and setting an ischemic threshold of 3 mV ST elevation. From these experiments, we extracted 35,633 ECGs and ischemic volumes, which were split into a 90% train 10% test set.

Results: After training our ML architecture to predict ischemic volume calculated from intramural measurements using body surface ECGs, we were able to predict the size of the ischemic regions within a root mean squared error of 2.52 mm^3. We then trained a separate network solely on the task of detecting the presence or absence of ischemia based on a threshold of at least five intramural needle electrodes with at least 3 mV ST elevation, which resulted in an area under the receiver operator curve of 0.96.

Discussion: These results demonstrate a novel application of ECG-ML tools to enhance clinical risk stratification of patients experiencing myocardial ischemia. Combining these ML-based identification of ischemic severity with traditional ECG analysis will allow for rapid, accurate, and robust risk stratification of patients earlier in the disease process. Future studies will look to combine these techniques with physics-based electrocardiographic imaging techniques for localizing myocardial ischemia, and transfer learning techniques to bridge these ML tools from animal to human ECGs.