Lead-wire Interchange Detection with Serial ECGs

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In the United States, the annual acquisition of hundreds of thousands of electrocardiograms (ECGs) raises concerns about potential lead-wire interchanges (LWI) that can mimic cardiovascular abnormalities. Prior efforts to address this issue through automatic classifiers, whether based on morphology or redundancy, have yielded mixed results in terms of specificity and sensitivity. However, with LWI prevalence typically below 0.1%, the need for a classifier with a specificity of 99.9% or higher becomes paramount to minimize false positives. This underscores the importance of developing a robust classifier with meticulously selected criteria.

This study took on a novel approach by employing deep learning techniques to analyze serial ECG differences to categorize 22 distinct LWI types, including 7 limb LWIs and 15 chest LWIs. The goal was to achieve true positive detection rates applicable and acceptable in real-world clinical settings. A dataset comprising 146,000 ECGs was meticulously curated, with pairs of serial ECGs generated for 25,700 patients, ensuring a broad representation of potential LWI scenarios. Greyscale ECG images were generated from specific regions of interest, particularly focusing on the QT intervals, serving as input data for a convolutional neural network (CNN) hyper-tuned to optimize performance across diverse LWI presentations.

The areas under the curve (AUC) for receiver operating characteristic (ROC) curves were 99% and above for all 22 LWIs. Additionally, positive predictive values (PPVs) were computed for each LWI type, considering different sensitivity thresholds. PPVs variations were observed across LWI types with the prevalence values for RA-LA (0.43%), RA-LL (0.29%), RL-RA or RL-LA (0.2%, and other LWIs (0.07%).

In conclusion, the utilization of a hyper-tuned ResNet-style CNN proved effective in addressing the complex challenge of LWI detection in ECGs with PPVs ranging from 42% to 78% for limb-lead interchanges and 25% to 63% for chest-lead interchanges in high quality diagnostic ECG settings.