Detection of left ventricular contractile dysfunction in patients with premature ventricular contractions using electrocardiogram trained using a deep learning model

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Background: Premature ventricular contractions (PVCs) are the most common arrhythmia affecting the ventricle. Frequent PVCs are associated with the development of PVC-cardiomyopathy (CM). It is known that the PVC burden has a direct correlation to the severity of left ventricular (LV) dysfunction. However, only 5% of patients with frequent PVCs (>10,000 per day) have associated PVC-CM. Thus, selecting patients for therapy options with drugs or catheter ablation is challenging, especially, when patients are asymptomatic with the PVCs.

Purpose: To train a deep learning model to predict the probability of low LV ejection fraction (LVEF) in patients with PVCs on a 12-lead electrocardiogram (ECG).

Methods: Using 69,440 paired 12-lead ECGs (containing at least one PVC), and echocardiogram data, including the left ventricular ejection fraction at Mayo Clinic, we trained a convolutional neural network to identify patients with ventricular dysfunction, defined as ejection fraction \( \leq 35\% \), using the ECG data alone. ECGs were acquired at a sampling rate of 500 Hz using a Marquette ECG machine (GE Healthcare) and stored using the MUSE data management system for later retrieval. Comprehensive 2-D or 3-D and Doppler echocardiography were available for all patients. We trained a convolutional neural network using the Keras framework with TensorFlow (Google). The ECG-echocardiogram pairs were divided into a 60:20:20 training:validation:test split.

Results: The mean age of the patients used to train the model was 69.9±13.0 years, and 65.2 percent of patients were male. The mean LVEF for this population was 52±14.9%, and the proportion of patients with low LVEF was 16.8 percent. The model yielded values for area under the curve, sensitivity, specificity, and accuracy of 0.897, 0.830, 0.813, and 0.816, respectively (Figure 1). A representative example of model prediction of normal LVEF and low LVEF is shown in Figure 2.

Conclusion: Using large-scale data, we have trained a highly accurate convolutional neural network with excellent predictive accuracy for LV systolic dysfunction using the surface ECG. Such a tool would be invaluable for cardiologists when risk-stratifying patients with frequent PVCs, especially those that are asymptomatic. Patients at risk will benefit from early referral to electrophysiologists for drug therapy and catheter ablation to mitigate the risk of PVC-CM.

ROC of Low-EF Model

Figure 1
Figure 2

A: EF=67 (score for low LVEF<0.0001)

B: EF=19 (score=0.765)