Diagnostic performance of a wearable ring-type device with deep learning analysis of photoplethysmography for detecting atrial fibrillation

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Introduction: Detecting atrial fibrillation (AF) at the early stage is challenging due to paroxysmal nature. Continuous monitoring of photoplethysmographic (PPG) signals by wearable device may aid to solve this issue. We aimed to develop a ring-type wearable device (the ring) to detect AF with a deep learning analysis of PPG signals and validate its diagnostic performance.

Methods: During 2018 to 2019, a total of 100 participants with persistent AF who underwent elective electrical cardioversion were enrolled. Both PPG by the ring and simultaneous single-lead electrocardiogram were recorded for each participant before and after the cardioversion over 15 minutes each. PPG data recorded by the ring were transmitted to the user's smartphone wirelessly. The rhythms of PPG data were validated with simultaneous electrocardiogram reviewed by two electrophysiologists. The ring was implemented with a convolutional neural network algorithm to analysis PPG data, and 5-fold cross-validation process evaluated its diagnostic performance. We also compared the deep learning algorithm to support vector machine, which has known to be one of the most accurate among non-deep-learning algorithms.

Result: A total of 13,038 PPG samples were generated by the ring device (5,850 for sinus rhythm and 7,188 for AF). The ring's diagnostic accuracy, sensitivity, specificity, positive predictive value, and negative predictive value were 96.9%, 99.0%, 94.3%, 95.6%, and 98.7%, respectively (Figure). Deep learning algorithm maintained the best results among all the algorithms. By durations of PPG samples, the ring’s diagnostic accuracies were 96.5%, 96.4%, 96.0%, 94.7%, and 90.6% for 25, 20, 15, 10, and 5 seconds, respectively. When utilizing the softmax probability function of the deep learning algorithm, the ring could improve diagnostic accuracy up to 99.0%, which was balanced by filtering 11.5% of the total samples. For sinus rhythm, the ring's performance decreased as increasing pulse-interval variability, but no definite trend for heart rate was observed. During AF rhythm, the ring with deep learning algorithm maintained high diagnostic performance regardless of pulse-interval variability or heart rate.

Conclusion: A ring-type wearable device with deep learning analysis of PPG signals showed high diagnostic performance. With this device, continuous monitoring for AF among the high-risk population may be promising.