Innovation in cardiology: telemedicine and artificial intelligence to manage heart failure

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BACKGROUND: Heart failure (HF) is a global disease with increasing prevalence in an aging society. Early identification of patients with a high risk of HF is important but challenging. The management of these patients is nowadays improved through the advances of telemedicine and Artificial Intelligence (AI). ECG is a cheap and readily available tool, perfect to identify patients who should have an echocardiogram examination. Nowdays, there is a variety of wearable devices which offer the possibility of detecting cardiac episodes while enabling patients to take their own ECG using a simplified method. Immense data generated from these devices have further encouraged development of algorithms based on AI thereby improving clinical effectiveness and ensuring continuity of care. AI can detect from ECG left ventricular systolic dysfunction (LVSD), which is associated with more than 8-fold increase in HF risks and to nearly 2-fold increase in risk of dying prematurely. This study aims to develop an AI-based model capable of predicting left ventricular ejection fraction (LVEF) from ECG data in a cohort of HF patients.

METHODS: The study was conducted with data from 105 patients (64.82±16.02 y; 62.86% male) from the University Hospital of Salerno Cardiology Clinic. Precisely, we excluded patients with atrial fibrillation at the time of the ECG, PMK or electro-stimulated rhythm, valve prostheses, previous cardiac surgery, O2 therapy or COPD, previous ablation or invasive electrophysiology procedures, currently hospitalized for Takotsubo or ACS, heart failure exacerbation, inotropic therapy, ACS in the previous 3 months. We recorded anthropometric, clinical, biochemical, echocardiographic and ECG parameters and pharmacological therapy. We employed specific AI-based techniques, based on an innovative algorithm and genetic programming, to provide a mathematical model of relationship between ECG parameters and LVEF. The formula obtained was then used to build a simple explainable classifier which, unlike existing tools such as LIME and SHAP, provides a global interpretation of the link between ECG parameters and LVEF.

RESULTS: The performance of the proposed approach and the reliability of the results were assessed using the k-fold cross-validation method, as well as by estimating common metrics derived from the confusion matrix associated with a binary classifier, that is accuracy, sensitivity, specificity, precision, and F-Measure.The proposed approach consistently demonstrated its ability to correctly distinguish patients with abnormal LVEF from those with normal LVEF. In fact, each metric, averaged across all experiments, achieved a score of approximately 95%. We would like to emphasize that our proposal is not based on a black-box machine learning approach, but instead, It provides an easily interpretable model expressed by a mathematical formula, which can help clinicians to better understand the dynamics of LVEF and plan the patients' treatment more effectively.

CONCLUSIONS: Artificial intelligence applied to ECG data can be used to create cost-effective diagnostic and predictive tools for assessing left ventricular function. Specifically, in the expression generated by the AI model, the axes of the P, QRS, and T waves play a prominent role, as they are likely to provide a better interpretation of the three-dimensional cardiac geometry and, consequently, cardiac function. Indeed, the obtained formula highlights the existence of the relationship between ECG parameters and LVEF, as well as its complexity. The suggested model could be useful to support telemedicine by employing wearable devices for early detection of heart diseases. However, although the proposal could offer real-time detection of heart disease, further studies are required to better understand its limitations and the factors influencing its accuracy.