Diagnosis and treatment of new heart failure with reduced ejection fraction by the artificial intelligence–enhanced electrocardiogram

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Introduction

Artificial intelligence (AI) is revolutionizing the way clinicians approach patient care. We have previously shown that application of an AI-enhanced electrocardiogram (AI-ECG) in emergency department patients with dyspnea can identify left ventricular systolic dysfunction (LVSD) with a high diagnostic accuracy through retrospective review.[1] As internal and external validations of the AI-ECG algorithm have yielded similarly accurate results, the broad application of this AI algorithm may be considered.[2,3]

Heart failure (HF) with reduced ejection fraction is a widely prevalent progressive disease, which, if unidentified and untreated, can lead to significant morbidity and mortality.[4] Symptomatic HF accounts for a significant portion of acute care visits, frequently because of dysnpea.[5] Often, the workup of dyspnea involves broad testing to exclude other conditions (ie, pulmonary embolism, pneumonia, anemia, etc) potentially delaying the diagnosis of and intervention for acute HF exacerbation.

In this case presentation, the application of the AI-ECG algorithm led to early diagnosis and treatment of acute HF exacerbation in a young patient with no cardiac disease history.

Case report

A 41-year-old man with a medical history of morbid obesity (class III; body mass index 64.7 kg/m^2) and obstructive sleep apnea (on home continuous positive airway pressure therapy) presented to an outpatient appointment with significant swelling of the lower extremities, abdomen, scrotum, and lower chest, which had progressed over 4 days. He experienced shortness of breath with this progressive edema and was hypertensive and tachycardic (systolic blood pressure 180 mm Hg; diastolic blood pressure 116 mm Hg; heart rate 113 beats/min). As a result, the patient was transferred to the nearest emergency department for continued workup.

While in the emergency department, the patient underwent a computed tomography scan of the abdomen and pelvis, which revealed a nodular liver, splenomegaly, and ascites suggestive of cirrhosis with portal venous hypertension. He was also noted to have elevated high-sensitivity troponin without significant delta of variation (85 ng/L; upper limit of normal [ULN] $\leq$15 ng/L), elevated N-terminal pro-B-type natriuretic peptide (2845 pg/mL; ULN $\leq$51 pg/mL), and elevated creatinine (1.66 mg/dL; ULN $\leq$1.35 mg/dL). The ECG showed sinus tachycardia, premature ventricular complexes with rightward deviation, and a nonspecific T-wave abnormality. He was admitted to the hospital for further workup and ongoing diuresis.

The patient recalled suffering from an upper respiratory tract infection 2 weeks prior with symptoms lasting 1 week in duration, terminating before developing worsening edema. Given his clinical history and laboratory findings concerning for potential new diagnosis of HF, a second ECG was obtained, and the AI-ECG dashboard was accessed to evaluate for the underlying cardiac abnormality (Figure 1). The 2 ECGs evaluated by the AI-ECG algorithm revealed high probabilities of reduced ejection fraction (97.88% and 98.67%) (Figure 1C). Consequently, the patient was continued on intravenous diuretics, and a transthoracic echocardiogram was obtained the following day. Echocardiography showed a left ventricular ejection fraction of 41% with global left ventricular hypokinesis. There was associated reduced right ventricular systolic function and elevated right ventricular systolic pressure (57 mm Hg) with bilateral atrial enlargement. Coronary computed tomography angiography demonstrated minimally obstructive calcified plaques in the left anterior descending

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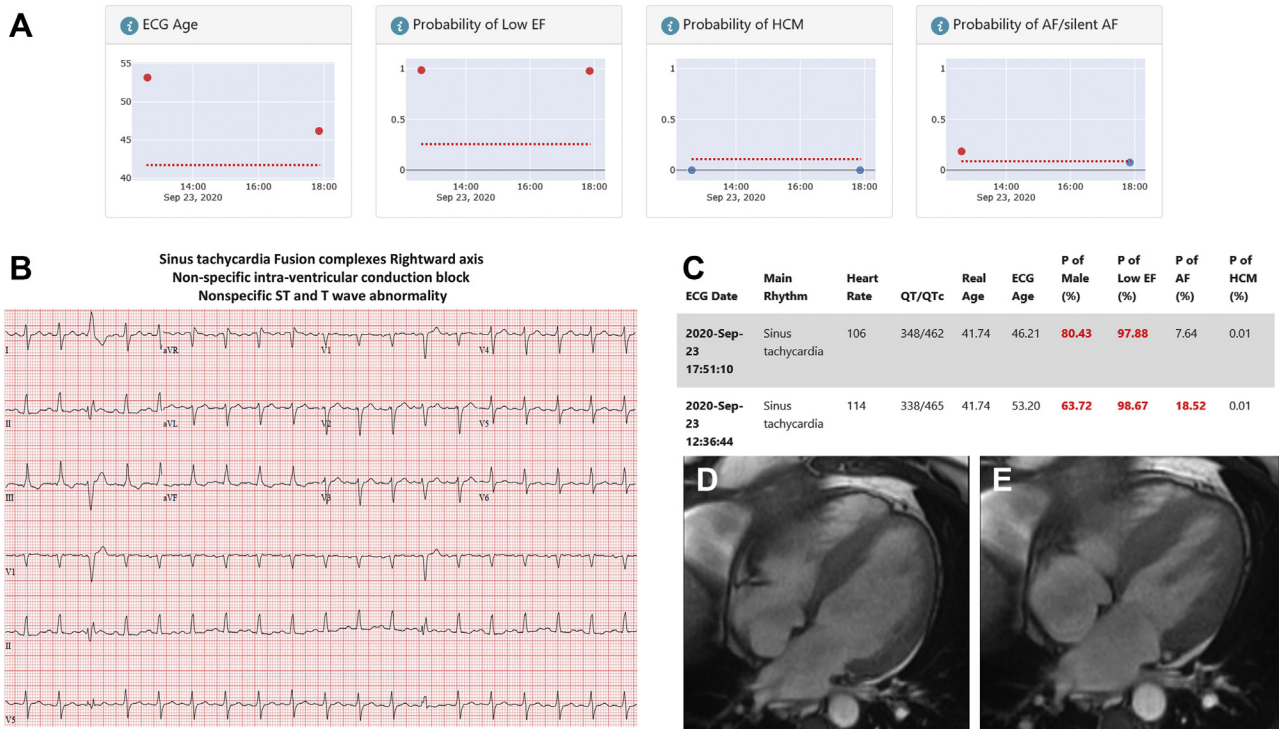

Figure 1 AI-ECG dashboard analysis of the patient's ECGs for multiple pathologies. **A:** AI-ECG analysis of the patient's obtained ECGs in our medical system. The algorithm estimates the patient's age from ECG (or physiologic "AI-ECG age") interpretation as well as probabilities of various cardiac pathologies (low EF, HCM, and AF). Each AI-evaluated ECG is represented in each pathology box by *red dots* as "increased likelihood" above our calculated diagnostic threshold and by *blue dots* for "low likelihood" for each pathology. This patient had 2 ECGs in our system, represented by 2 dots in each AI-ECG box. **B:** The patient's most recently recorded ECG. **C:** The numerical probability values for each pathology screened by the AI-ECG for each ECG in our medical system. The *red values* correlate with those percentages higher than our diagnostic threshold ("increased likelihood," also represented in panel A by *red dots*). In this case, the probability of low EF was exceedingly high (97%–98%) in each of the patient's AI-ECGs. **D:** Diastole. **E:** Systole. Cardiac magnetic resonance imaging confirmed the patient's significant biventricular HF with reduced EF. AF = atrial fibrillation; AI-ECG = artificial intelligence–enhanced electrocardiogram; EF = ejection fraction; HCM = hypertrophic cardiomyopathy; HF = heart failure; P = probability; QTc = corrected QT.

artery; cardiac magnetic resonance imaging demonstrated global hypokinesis with mid-myocardial delayed enhancement with an associated left ventricular ejection fraction of 34% and a right ventricular ejection fraction of 29% (Figures 1D and 1E).

The patient was initiated on guideline-directed medical therapy for newly diagnosed HF with reduced ejection fraction, and at a 4-month follow-up visit, the patient had improved left ventricular ejection fraction to 55% on the transthoracic echocardiogram. This improvement was likely a result of goal-directed medical management of HF, recovery from post-viral sequelae, and significant weight loss due to lifestyle changes (body mass index to 45.73 kg/m^2 at follow-up).

Patient consent was obtained before the submission of this case report.

Discussion

The AI-ECG greatly assisted in expedited diagnosis of new HF with reduced ejection fraction in a patient with no known cardiac disease history. This algorithm identified ventricular dysfunction despite confounding factors including potential cirrhosis and portal hypertension suggested by emergency department imaging, elevated creatinine potentially affecting cardiac biomarkers, and nonspecific ECG findings via manual review. As ECGs are a routinely available cost-effective test performed at the bedside, the addition of AI to the standard ECG, which is already embedded in medical workflows, stands to add significant clinical value to cases, like this one, where the pretest probability is intermediate and further cardiac workup (ie, transthoracic echocardiogram) may not otherwise be considered.[6,7]

In our previous work, we described our AI algorithm, which is able to detect LVSD from an ECG by use of a convolutional neural network trained with Keras with TensorFlow (Google, Mountain View, CA).[1,8] This algorithm showed robust performance when tested in both the asymptomatic population and those with acute HF exacerbation in the emergency department in retrospective cohort studies.[1,8] Recently, prospective application of the algorithm lead to increased early diagnosis of LVSD through community screening with AI-ECGs.[9,10] We hope that this case similarly exemplifies the algorithm's robust performance and diagnostic utility in the acute dyspneic patient with a confounding clinical presentation.

This patient's clinical picture was particularly interesting given his recent history of an upper respiratory illness. The AI-ECG algorithm has previously shown high diagnostic accuracy in detecting LVSD in the setting of coronavirus disease 2019 (COVID-19) infeciton.[11] Although this patient

had not suffered from a COVID-19 infection (severe acute respiratory syndrome coronavirus 2 antibodies negative during hospitalization), the AI-ECG accurately identified new HF in the post-viral setting, suggesting that this algorithm may also find clinical utility in detecting non–COVID-19, viral cardiomyopathies.

As exemplified in this case, the AI-ECG algorithm for LVSD may expedite the evaluation of complex clinical cases in which multiple confounding factors are present and multiple diagnoses were under consideration. Prospective evaluation of the AI-ECG for ventricular dysfunction for expedited diagnosis and treatment of HF in the acute setting will be an area of future study.

Guidelines statement

The research reported in this article adhered to the CARE case report guidelines.

Disclaimer

Given his role as Section Editor, Zachia Attia had no involvement in the peer review of this article and has no access to information regarding its peer review.

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