Electrocardiogram-based mortality prediction in patients with COVID-19 using machine learning

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Background

The electrocardiogram (ECG) is an easy to assess, widely available and inexpensive tool that is frequently used during the work-up of hospitalized COVID-19 patients. So far, no study has been conducted to evaluate if ECG-based machine learning models are able to predict all-cause in-hospital mortality in COVID-19 patients.

Purpose

With this study, we aim to evaluate the value of using the ECG to predict in-hospital all-cause mortality of COVID-19 patients by analyzing the ECG at hospital admission, comparing a logistic regression based approach and a DNN based approach. Secondly, we aim to identify specific ECG features associated with mortality in patients diagnosed with COVID-19.

Methods and results

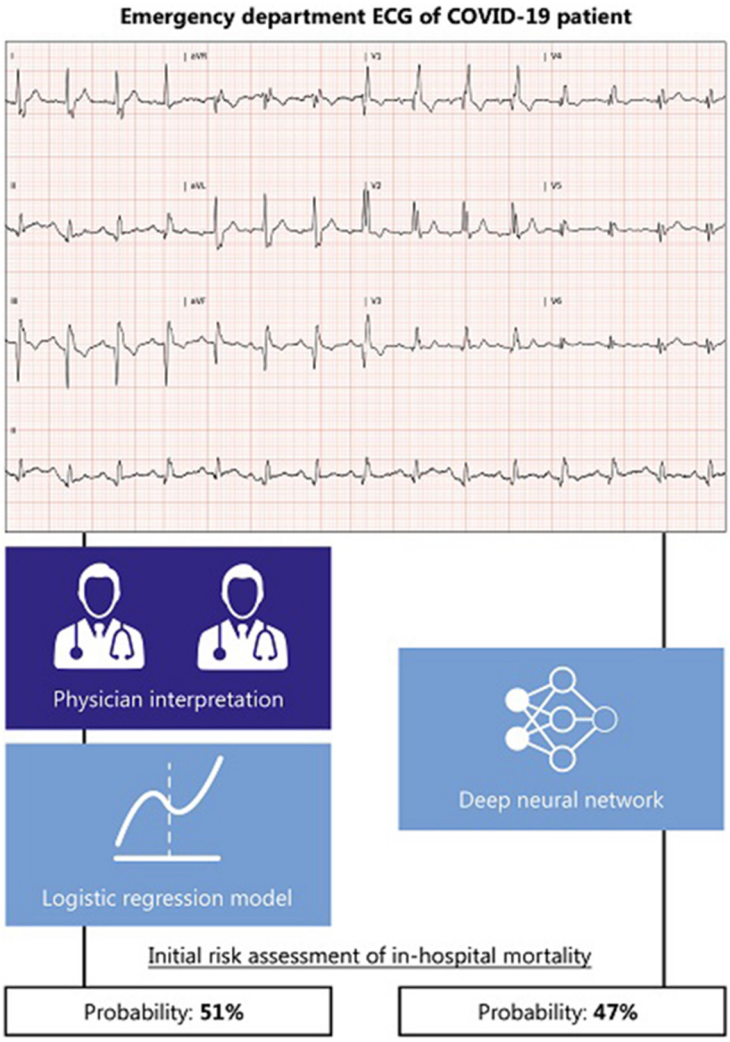
We studied 882 patients admitted with COVID-19 across seven hospitals in the Netherlands. Raw-format 12-lead ECGs recorded after admission (<72 hours) were collected, manually assessed, and annotated using pre-defined ECG features. Using data from five out of seven centers (n = 634), two mortality prediction models were developed: (a) a logistic regression model using manually annotated ECG features, and (b) a pre-trained deep neural network (DNN) using the raw ECG waveforms. Data from two other centers (n = 248) were used for external validation. Performance of both prediction models was similar, with a mean area under the receiver operating curve of 0.69 [95%CI 0.55–0.82] for the logistic regression model and 0.71 [95%CI 0.59–0.81] for the DNN in the external validation cohort. After adjustment for age and sex, ventricular rate (OR 1.13 [95% CI 1.01–1.27] per 10 ms increase), right bundle branch block (3.26 [95% CI 1.15–9.50]), ST-depression (2.78 [95% CI 1.03–7.70]) and low QRS voltages (3.09 [95% CI 1.02-9.38]) remained as significant predictors for mortality.

Conclusion: This study shows that ECG-based prediction models at admission may be a valuable addition to the initial risk stratification in admitted COVID-19 patients. The DNN model showed similar performance to the logistic regression that needs time-consuming manual annotation. Several ECG features associated with mortality were identified.

Figure 1:

Overview of methods, using and example case: (left) logistic regression and (right) deep learning. This specific case had a high probability of in-hospital mortality (above the threshold of 30%). Follow-up of this case showed that the patient had died during admission.

Abstract Figure. Overview of ML methods used


Emergency department ECG of COVID-19 patient
Physician interpretation
Deep neural network
Logistic regression model
Initial risk assessment of in-hospital mortality
Probability: 51%
Probability: 47%