A Machine Learning Model For Predicting Deterioration of COVID-19 Inpatients

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Background

The COVID-19 pandemic has been spreading worldwide since December 2019, presenting an urgent threat to global health. Due to the limited understanding of disease progression and of the risk factors for the disease, it is a clinical challenge to predict which hospitalized patients will deteriorate. Early prediction can allow physicians to take measures that prevent or lessen condition worsening.

Our goal is to develop a predictive model for the early identification of patients at risk for clinical deterioration by analyzing Electronic Medical Records (EMR) data of COVID-19 inpatients.

Datasets

The *development set* contains medical records of 662 inpatients admitted to the Sheba Medical Center (Sheba) between March and December 2020, who were diagnosed with COVID-19.
The *validation set* contains medical records of 417 inpatients admitted to the Tel-Aviv Sourasky Medical Center (TASMC) between March and September 2020, who were diagnosed with COVID-19.

SHEBA Tel HaShomer City of Health **N = 662**   **Tel-Aviv Sourasky Medical Center** **N = 417**

The data used was extracted from longitudinal EMRs and included both time-independent (static) and temporal (dynamic) features, such as demographics, background disease, vital signs and lab measurements. A total of **100 features** were selected per patient.

Target Definition

The National Early Warning Score 2 (NEWS2) is used as a clinical risk score for early recognition of patients with severe infection. Liao et al. (2020) suggested an early warning score for COVID-19 patients termed "modified-NEWS2" (mNEWS2), which adds to the NEWS2 formula the factor age ≥ 65 years.
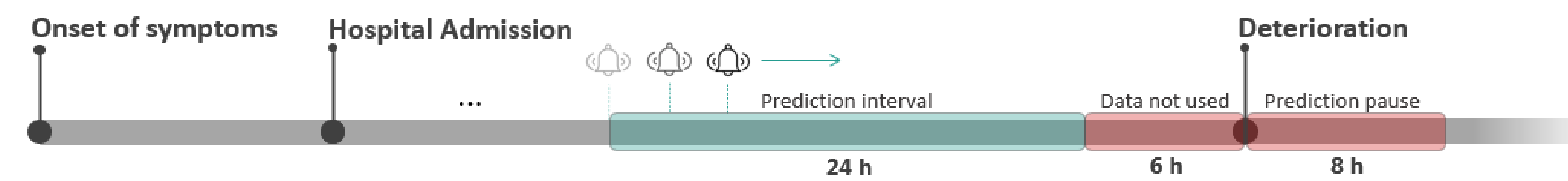
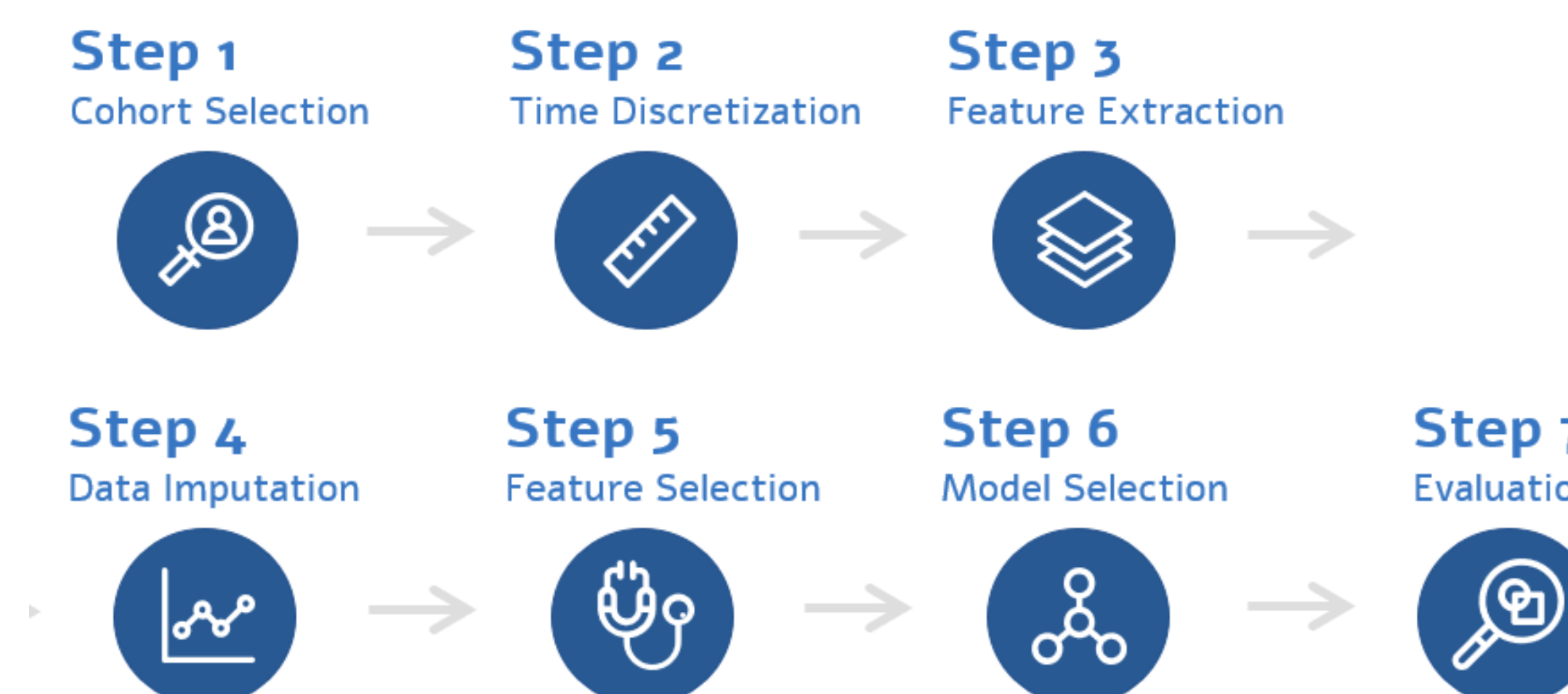| Points	3	2	1	0	1	2	3
Age				<65			≥65
Respiratory Rate	≤8		9-11	12-20		21-24	≥25
Oxygen Saturation	≤91	92-93	94-95	≥96			
Supplemental Oxygen		Yes		No			
Systolic BP	≤90	91-100	101-110	111-219			≥220
Heart Rate	≤40		41-50	51-90	91-110	111-130	≥131
Consciousness				Alert			Drowsiness Letargy Coma Confusion
Temperature	≤35.0		35.1-36.0	36.1-38.0	38.1-39.0	≥39.1	

The mNEWS2 score (Liao et al, 2020)

→ **mNEWS2≥7**

Observations with a high mNEWS2 score (≥7) recorded in the preceding 7-30 hours were called **positive**, and the rest were called negative. We did not use the data in 6 hours prior to the event.


Model Development Overview

Step 1 Cohort Selection → **Step 2** Time Discretization → **Step 3** Feature Extraction

Step 4 Data Imputation → **Step 5** Feature Selection → **Step 6** Model Selection → **Step 7** Evaluation

Model Selection

The performance of 14 machine learning models that predict mNEWS2≥7 was tested, using 10-fold cross-validation over the training set. We chose CatBoost as our final prediction model.
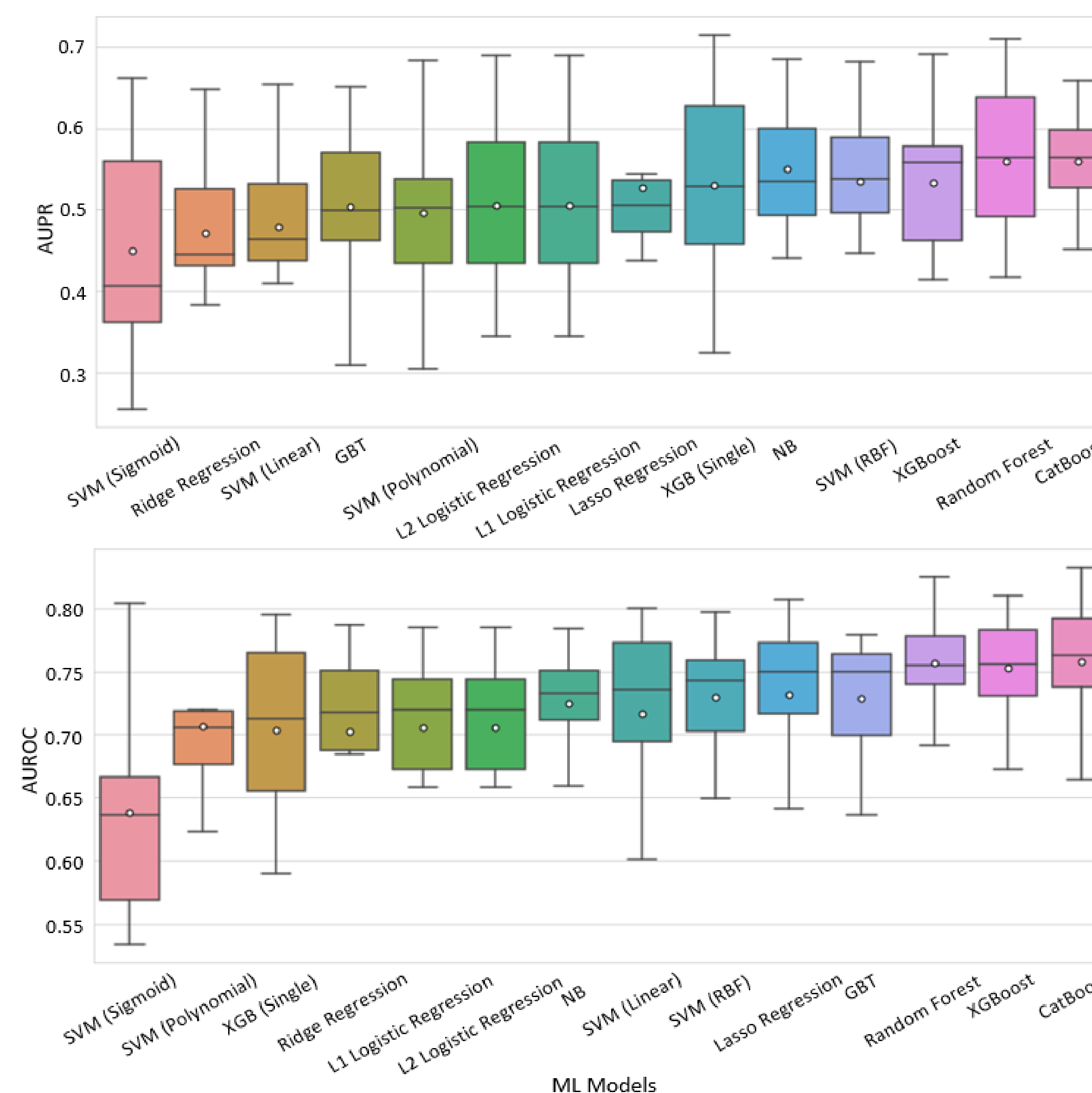
Results
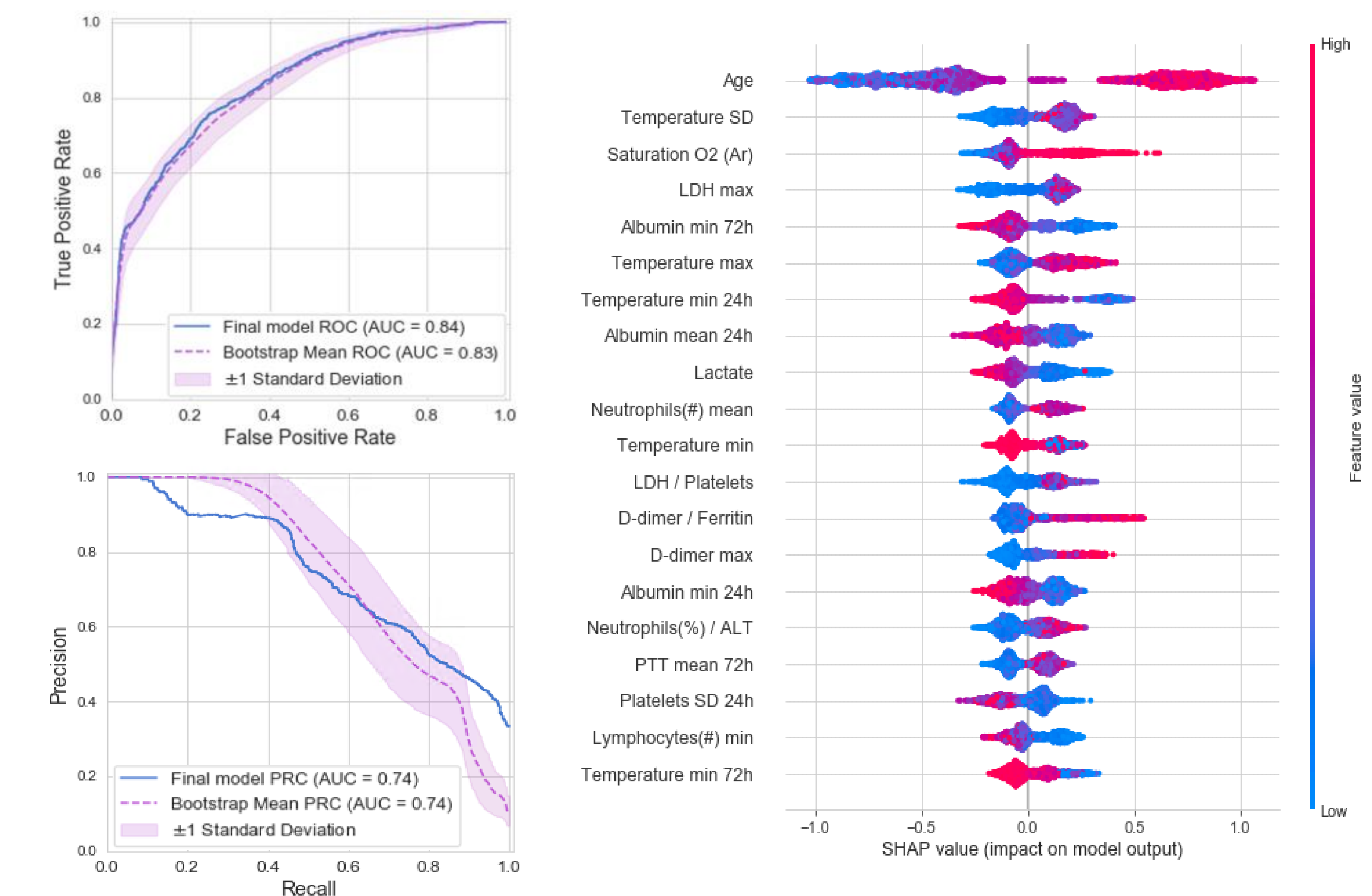
External validation: The final model achieved **AUROC=0.76** and **AUPR=0.7** in external validation on the TASMC data, slightly less than in the development dataset.

Conclusions and Future Work

We utilized machine learning models for predicting deterioration within the next 7-30 hours based on EHR data of COVID-19 inpatients. On held-out data, the model achieved AUROC of 0.84 and AUPR of 0.74. It achieved values of 0.76 and 0.7 respectively in external validation on data from a different hospital.

Future work:
- Models for early warning on approaching oxygen deficiency deterioration events.
- Multi-center model training.
- Comparative analysis across different COVID-19 waves.
- Existing models benchmarking.