31. A Machine Learning-Based Prediction Model of Hospital Mortality in Mechanically Ventilated Patients With Congestive Heart Failure

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Background: Mechanically ventilated patients with congestive heart failure (CHF) have high rates of mortality. We aimed to establish a machine learning (ML)-based prediction model for in-hospital death and identify the risk factors in mechanically ventilated patients with CHF.

Methods: Patient data were retrospectively collected from a single medical center. Several ML algorithms were used to build the prediction model. Recursive feature elimination (RFE) and hyperparameters optimization (HPO) were employed to select the key features and modify the model, respectively. Model evaluation methods utilized included area under the receiver operating characteristic curve (AUC), accuracy, F1-score, calibration curve and decision curve analysis. The external validation was conducted using the data from the eICU database.

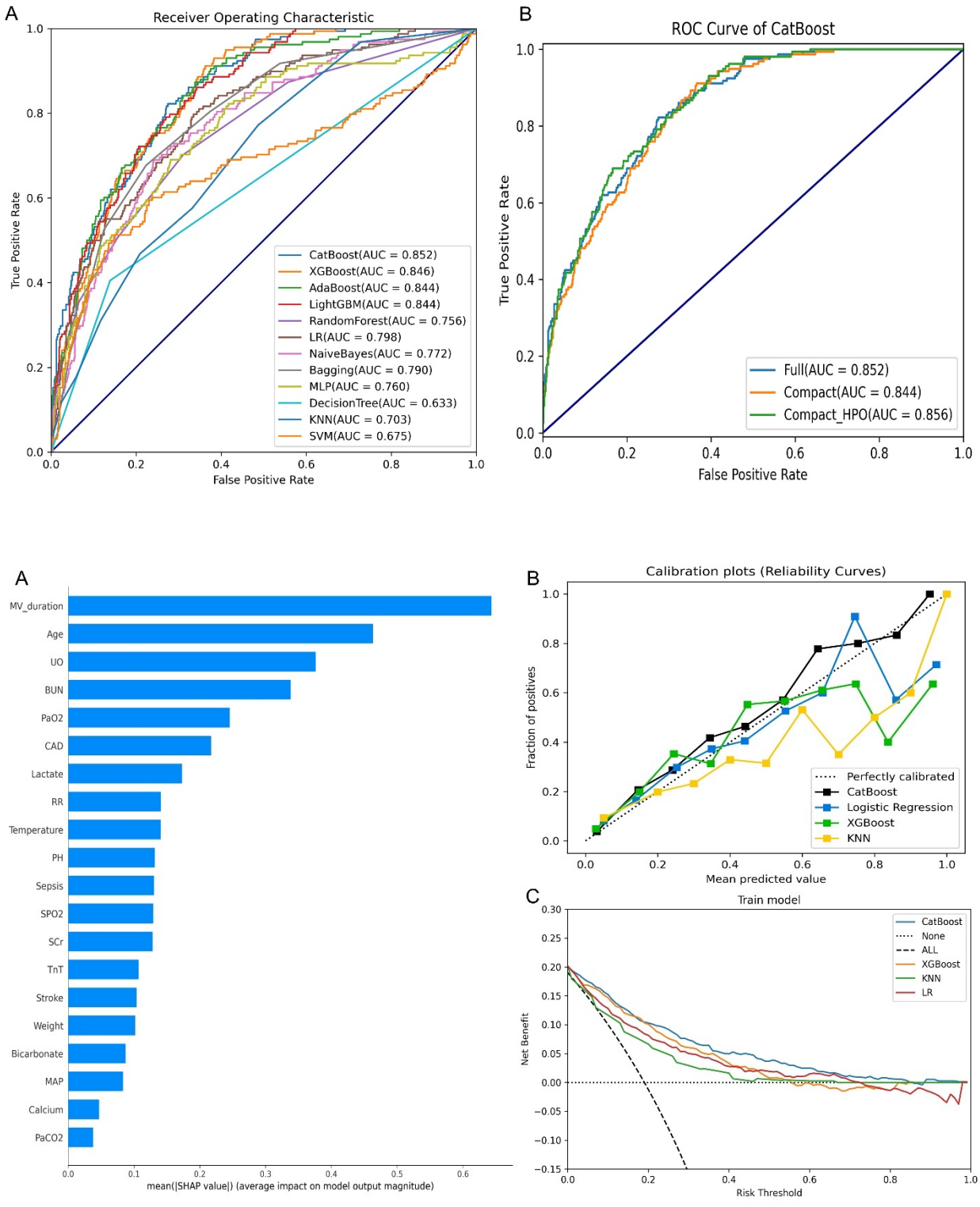
Results: A total of 3916 mechanically ventilated patients with CHF were included, among whom 719 died during hospitalization. The CatBoost model showed the best prediction performance among the 12 common used ML algorithms, with AUC of 0.852 (Figure 1A). After RFE, 20 of the 63 features including duration of mechanical ventilation, age and urine output were selected as the key features based on the feature importance. And the discrimination of the CatBoost model was significantly improved through HPO (AUCs: 0.844 vs. 0.856) (Figure 1B). After RFE and HPO, the final model with 20 key features was established (Figure 2A). The favorable outcomes of the CatBoost model were also shown in the calibration curve and the decision cureve (Figure 2B-2C). As shown in the Table 1, the CatBoost model had the best accuracy and positive prediction value. Finally, external validation using the eICU database comprising 2367 ventilated patients with CHF revealed satisfactory prediction outcomes (AUC = 0.831).

Conclusion: Duration of mechanical ventilation, age, urine output, urea nitrogen and partial pressure of oxygen were strongly associated with hospital mortality, and the CatBoost model could accurately predict in-hospital death in ventilated patients with CHF.

Table 1. Comparisons of the models' performance based on the 20 key features.

Model	AUC	Accuracy, %	PPV, %	NPV, %	BA, %	F1-score
Internal validation						
CatBoost	**0.856**	**83.5**	**72.3**	84.6	63.4	0.422
XGBoost	0.823	81.0	55.8	83.7	60.9	0.366
AdaBoost	0.829	81.6	58.8	84.2	62.2	0.395
LightGBM	0.833	81.4	61.1	82.9	58.8	0.311
Random Forest	0.764	80.6	55.4	82.6	57.8	0.290
LR	0.781	82.0	66.7	83.1	59.4	0.325
Naïve Bayes	0.696	79.8	50.0	80.1	50.9	0.048
Bagging	0.797	80.6	54.8	82.8	58.5	0.309
MLP	0.780	79.0	47.6	**86.1**	**65.8**	**0.455**
Decision Tree	0.626	76.5	41.3	84.9	62.6	0.403
KNN	0.718	80.4	58.3	81.1	53.6	0.154
SVM	0.717	80.1	57.1	80.5	52.1	0.093
External validation						
CatBoost	**0.831**	**83.0**	72.7	83.8	61.5	0.376
XGBoost	0.818	83.0	67.6	84.6	**63.4**	**0.419**
AdaBoost	0.800	81.9	60.3	84.3	62.4	0.398
LightGBM	0.822	82.5	**77.2**	82.9	62.0	0.391
Random Forest	0.808	80.9	61.1	81.8	55.8	0.227
LR	0.779	80.5	55.1	82.2	56.8	0.261
Naïve Bayes	0.714	79.3	37.5	80.2	51.1	0.069
Bagging	0.760	81.4	59.4	83.3	59.9	0.342
MLP	0.740	80.7	53.5	**84.7**	63.1	0.412
Decision Tree	0.673	78.2	52.6	82.4	57.3	0.279
KNN	0.663	77.9	52.3	80.8	52.9	0.133
SVM	0.721	79.8	50.0	80.6	52.4	0.112

AUC: area under the receiver operating characteristic curve; PPV: positive prediction value; NPV: negative prediction value; BA: balanced accuracy.



Clinical Implications: My study will help enable cardiovascular clinicians to early identify the mechanically ventilated patients with congestive heart failure who are at high-risk of in-hospital death.