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Predictive Model of Multi-Drug Resistant Urinary Tract Infections Using Machine Learning in Patients with Spinal Cord Injury

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Objective

Urinary tract infections (UTIs) are common complications in individuals with spinal cord injuries (SCI). Despite advancements in treatment, multidrug-resistant UTIs pose a growing concern. This study aimed to develop a predictive model for multidrug-resistant UTIs in SCI patients by employing machine learning techniques and to assess the clinical potential of the model in real-world clinical settings.

Methods

We retrospectively reviewed the medical records of individuals with SCI who were admitted to the department of rehabilitation medicine at Severance Hospital from October 2015 to September 2023. We investigated the performances of machine learning models—logistic regression, naïve Bayes, random forest, support vector classifier, XGBoost, and combination models—that were designed for the prediction of multidrug-resistant UTIs in individuals with SCI. For each model, accuracy, sensitivity, specificity, and area under the curve of the receiver operating characteristic curve were calculated. Among the candidate hyperparameters, those that maximize area under the curve of the receiver operating characteristic curve in the validation set were selected. Statistical analysis was conducted using R Studio v.4.2.3 and the Python scikit-learn library v.1.0.2.

Results

A total of 252 patients were enrolled. The dataset was divided into a training set and a test set in a 7:3 ratio, resulting in 176 and 76 patients in each group, respectively. A combination model of naive Bayes and XGBoost demonstrated the most superior performance, exhibiting an accuracy of 0.8684, sensitivity of 0.8571, and specificity of 0.0.8727. The AUROC was measured at 0.8823. Among the variables, high feature importance was observed for the following: neutrophil count, neutrophil to platelet ratio, SCIM-3, usage of beta-lactams within 30 days, neutrophil segment, hematocrit, neutrophil to lymphocyte ratio, hemoglobin, lymphocyte count, FIM, usage of antibiotics within 30 days, platelet count, albumin, age, protein, MBI, urine pH, hematuria, and proteinuria.

	Accuracy	Sensitivity	Specificity	PPV	NPV	AUROC
LR	0.7763	0.7143	0.8000	0.5769	0.8800	0.8545
NB	0.8553	0.9048	0.8364	0.6786	0.9583	0.8719
RF	0.7895	0.4762	0.9091	0.6667	0.8197	0.8468
SVC	0.8684	0.7619	0.9091	0.7619	0.9091	0.8398
XGB	0.7763	0.5714	0.8545	0.6000	0.8393	0.8390
NB+SVC	0.8684	0.8571	0.8727	0.7200	0.9412	0.8823

TABLE 1. Predictive performance of the machine learning models.

*LR, logistic regression; NB, naïve Bayes; RF, random forest; SVC, support vector classifier; XGB, XGBoost; PPV, positive predictive value; NPV, negative predictive value; AUROC, area under the curve of the receiver operating characteristic curve.

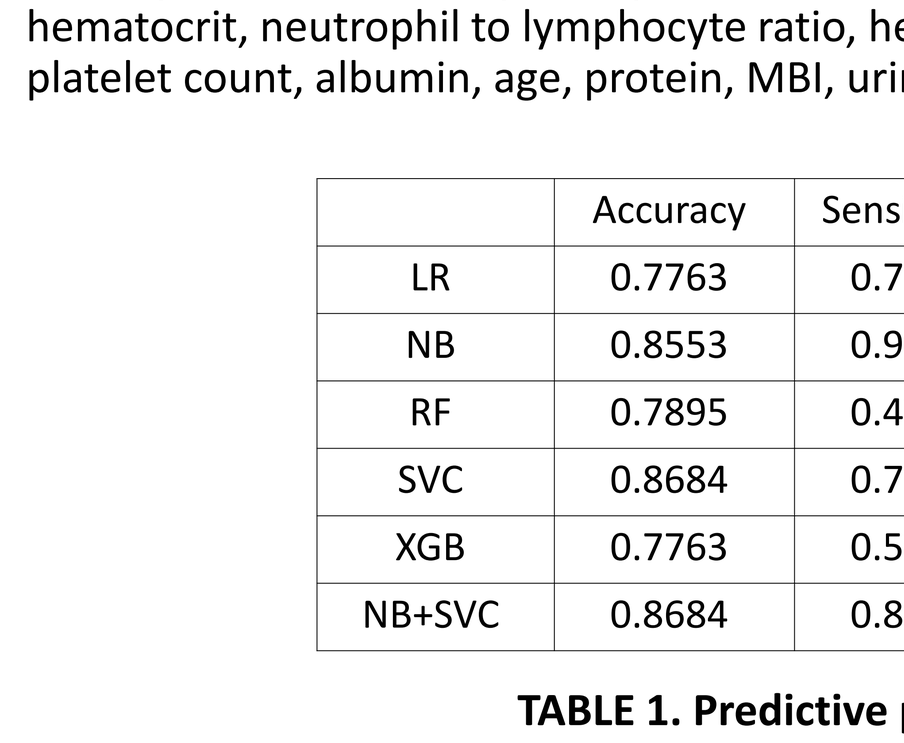

FIGURE 1. ROC curve for the prediction of multi-drug resistant UTI.

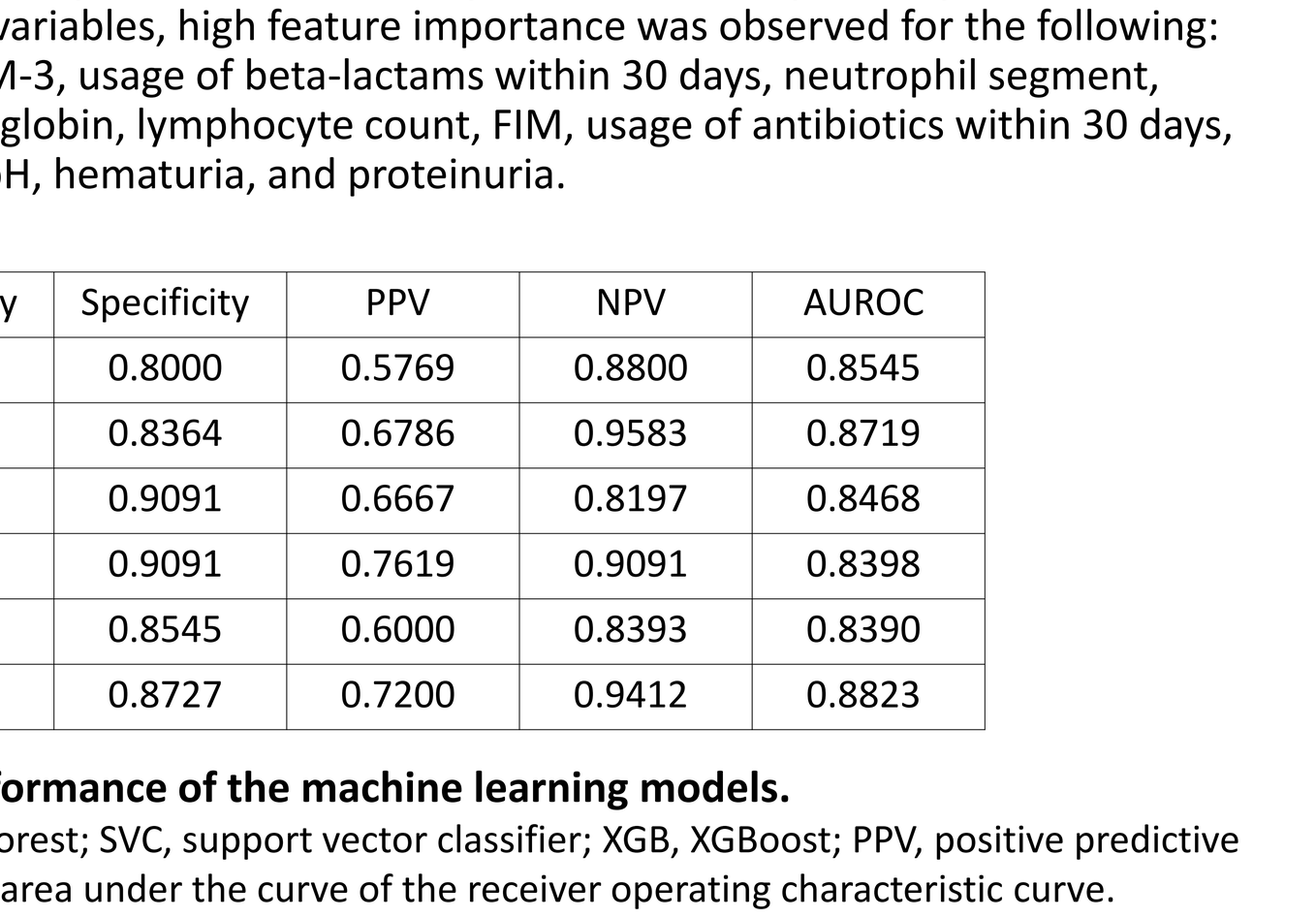

FIGURE 2. Feature importance of the proposed model.

Conclusion

The use of machine learning enabled the prediction of the likelihood of a multi-drug-resistant UTI based on the patient's condition at the time of admission. Furthermore, it is anticipated that utilizing this model will allow careful management for the prevention of UTI and consideration of antibiotic usage in future SCI patients.