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An intelligent warning model for early prediction of cardiac arrest in sepsis patients

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ABSTRACT

Background: Sepsis-associated cardiac arrest is a common issue with the low survival rate. Early prediction of cardiac arrest can provide the time required for intervening and preventing its onset in order to reduce mortality. Several studies have been conducted to predict cardiac arrest using machine learning. However, no previous research has used machine learning for predicting cardiac arrest in adult sepsis patients. Moreover, the potential of some techniques, including ensemble algorithms, has not yet been addressed in improving the prediction outcomes. It is required to find methods for generating high-performance predictions with sufficient time lapse before the arrest. In this regard, various variables and parameters should also been examined.

Objective: The aim was to use machine learning in order to propose a cardiac arrest prediction model for adult patients with sepsis. It is required to predict the arrest several hours before the incidence with high efficiency. The other goal was to investigate the effect of the time series dynamics of vital signs on the prediction of cardiac arrest.

Method: 30 h clinical data of every sepsis patients were extracted from Mimic III database (79 cases, 4532 controls). Three datasets (multivariate, time series and combined) were created. Various machine learning models for six time groups were trained on these datasets. The models included classical techniques (SVM, decision tree, logistic regression, KNN, GaussianNB) and ensemble methods (gradient Boosting, XGBoost, random forest, balanced bagging classifier and stacking). Proper solutions were proposed to address the challenges of missing values, imbalanced classes of data and irregularity of time series.

Results: The best results were obtained using a stacking algorithm and multivariate dataset (accuracy = 0.76, precision = 0.19, sensitivity = 0.77, f1-score = 0.31, AUC= 0.82). The proposed model predicts the arrest incidence of up to six hours earlier with the accuracy and sensitivity over 70%.

Conclusion: We illustrated that machine learning techniques, especially ensemble algorithms have high potentials to be used in prognostic systems for sepsis patients. The proposed model, in comparison with the exiting warning systems including APACHE II and MEWS, significantly improved the evaluation criteria. According to the results, the time series dynamics of vital signs are of great importance in the prediction of cardiac arrest incidence in sepsis patients.

Abbreviations: Acc, Accuracy; APPACHE, Acute Physiologic And Chronic Health Evaluation; AUC, Area Under ROC Carve; B, Balancing; BM, Bedside Monitor; bp, Blood Pressure; CA, Cardiac Arrest; CHP, Configuration Hyper Parameters; D, Dataset; DSR, Design Science Research; DT, Decision Tree; ECG, Electrocardiogram; ENR, Electronic Nursing Record; EHR, Electronic Health Record; F1, F1-score; FPR, False Positive Rate; FS, Feature Selection; GLM, Generalized Linear Model; HRV, Heart Rate Variability; ICU, Intensive Care Unit; KNN, K-Nearest Neighbor; LAB, laboratory; LR, Logistic Regression; MEWS, Modified Early Warning Score; MICE, Multivariate Imputation by Chained Equations; MLT, Machine Learning Technique; NB, Naïve Byes; NN, Neural Network; Prec, Precision; RF, Random Forest; ROSC, Return of Spontaneous Circulation; Sen, Sensitivity; Spec, Specificity; SVM, Support Vector Machine; T, Time.

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