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Literature review

Introduction

Stroke is a significant global health concern, ranking as the second-leading cause of death and the third-leading cause of disability worldwide. Hypertension is a key modifiable risk factor for stroke, significantly impacting the prognosis of patients with acute ischemic or hemorrhagic stroke. The incidence of ischemic stroke is notably higher than hemorrhagic stroke, with ischemic stroke accounting for approximately 87% of all stroke cases. This study aims to predict 28-day in-hospital mortality for hypertensive ischemic or hemorrhagic stroke patients in the ICU. The data for this study were obtained from the Medical Information Mart for Intensive Care IV (MIMIC-IV) database and the Collaborative Research Database (eICU-CRD). The analysis included 41 predictor features, including demographics, laboratory tests, and comorbidities. [1]

XGBoost Model Performance

The XGBoost model demonstrated excellent performance (AUC > 0.7), with feature importance analysis revealing that glucose, age, SpO2, WBC, ethnicity, calcium, BUN, MCV, RDW, bicarbonate, and hyperlipidemia were among the most important predictors. This study utilized SHapley Additive exPlanations (SHAP) values and feature significance to provide insights into predictors' contributions to the models. The following features were identified as influencing the most predictive models:

- Laboratory tests: Glucose, white blood cell count (WBC), calcium (Ca), blood urea nitrogen (BUN), mean corpuscular volume (MCV), red blood cell distribution width (RDW), and bicarbonate.
- Vital signs: Peripheral oxygen saturation (SpO2).
- Comorbidities: Hyperlipidemia.

Demographic factors, including age and ethnicity, also significantly impacted most predictive models. The study noted that the higher the SHAP value of a feature, the higher the risk of death for the patient. [1]

Additionally, the study identified the following independent risk factors for the ischemic stroke and hemorrhagic stroke subgroups:

- Ischemic stroke: Ethnicity, SpO2, age, MCV, RDW, BUN, calcium, glucose, hyperlipidemia, and WBC.
- Intracerebral hemorrhage: Ethnicity, age, MCV, RDW, calcium, hyperlipidemia, and WBC.

Discussion

The predictive model analysis revealed several key points:

- Elevated glucose levels emerged as the most critical indicator of in-hospital mortality, showing a direct association with increased 28-day death rates among hypertensive ischemic or hemorrhagic stroke patients in the intensive care unit (ICU).

- The risk of death was higher in hypertensive stroke patients with hyperlipidemia.
- Patients over 71.27 years were at a higher risk of an unfavorable outcome than younger patients.
- Ethnicity was also a significant demographic factor.
- Laboratory tests, such as WBC, calcium, MCV, RDW, BUN, and bicarbonate, played essential roles in the prediction model.
- Elevated WBC count was associated with increased in-hospital mortality in both ischemic and hemorrhagic stroke.
- Elevated MCV, RDW, and BUN levels were associated with increased in-hospital mortality.
- Lower bicarbonate levels, which may suggest metabolic acidosis, indicated a higher mortality risk.
- Vital sign SpO2 was not significant in the intracerebral hemorrhage group. [1]

Additional studies

A study of the Prediction of in-hospital stroke mortality in critical care units examines key predictors of in-hospital mortality in acute stroke patients focusing on ischemic and hemorrhagic strokes. In this study, they used the NIHSS score, a measure of stroke severity, which has consistently been identified as a strong predictor of in-hospital mortality in both ischemic and hemorrhagic stroke patients. [2]

For Ischemic Stroke, they identified the following critical predictors for In-hospital mortality.

- Age: Advanced age is a well-established predictor of poor outcomes in ischemic stroke, including increased mortality risk. Older patients often have more comorbidities and reduced physiological reserves, contributing to higher mortality rates.
- White Blood Cell Count: The elevated WBC count, indicative of systemic inflammation, has been associated with increased mortality in ischemic stroke patients.
- Systolic Blood Pressure: Abnormal BP values, particularly hypotension, may indicate underlying hemodynamic instability and poor prognosis.

Moreover, for Hemorrhagic Stroke, they stated the following key predictors for In-hospital mortality.

- Systolic Blood Pressure: Abnormal systolic BP levels, particularly hypotension, have been linked to increased mortality risk in hemorrhagic stroke patients. Hemodynamic instability may exacerbate bleeding and lead to poor outcomes.
- Heart Disease History: Pre-existing heart disease, including heart failure, arrhythmias, and ischemic heart disease, has been identified as a predictor of in-hospital mortality in hemorrhagic stroke patients. Cardiac comorbidities may contribute to hemodynamic instability and worsen outcomes.
- Creatinine (Cr) Level: Elevated serum creatinine levels, indicative of impaired renal function, have been associated with increased mortality in hemorrhagic stroke patients. Renal dysfunction may reflect overall disease severity and contribute to poor prognosis. [2]

Another study of Outcome Predictors of Stroke Mortality in the Neurocritical Care Unit conducted in Kazakhstan suggests that the mortality risk in critically ill patients with hemorrhagic stroke was closer to the mortality risk in patients with ischemic stroke. They furthermore stated that Hypertension, chronic heart failure, ischemic heart disease, and atrial fibrillation were the most frequent comorbidities in patients who developed severe stroke. They identified the following vital predictors for Predicting Mortality in Hypertensive Ischemic or Hemorrhagic Stroke Patients. [3]

- Glasgow Coma Scale (GCS) Score: A lower GCS score at admission was significantly associated with higher in-hospital mortality. Patients who were in a coma (GCS < 9) had a higher risk of mortality.
- Cerebral Edema: The presence of cerebral edema on admission was significantly correlated with an increased risk of mortality. Patients with cerebral edema were more likely to die in the hospital.
- Stroke Type: While not statistically significant, hemorrhagic stroke trended toward a lower risk of in-hospital mortality compared to ischemic stroke in multivariable analysis. They suggest that stroke type may play a role in predicting mortality, with hemorrhagic stroke patients having a slightly better outcome.
- Gender: Male sex was associated with a lower risk of in-hospital mortality in multivariable analysis.
- Age: While not explicitly mentioned in the study as a predictor, age is a well-established risk factor for stroke mortality. Older age is generally associated with a higher risk of mortality in stroke patients.
- Comorbidities: The study identified Hypertension, chronic heart failure, ischemic heart disease, and atrial fibrillation as the most frequent comorbidities in patients who developed severe stroke. These comorbidities may contribute to an increased risk of mortality in stroke patients.
- Neurocritical Care Unit Admission Criteria: Admission criteria to the neurocritical care unit, such as impaired consciousness (GCS ≤ 12), need for mechanical ventilation, and clinically significant brain edema, were essential to identify patients at higher risk of mortality.
- Myocardial Infarction: While not explicitly highlighted in the predictors, the study mentioned that a small percentage of patients developed myocardial infarction, which is a severe complication that could contribute to mortality in stroke patients.
- Management of Complications: The study highlighted the importance of managing complications such as respiratory failure, gastrointestinal bleeding, and myocardial infarction, which can significantly impact mortality in stroke patients. [3]

Overall, this study emphasizes the importance of early recognition and management of factors such as GCS score, cerebral edema, stroke type, and comorbidities in predicting mortality in hypertensive ischemic or hemorrhagic stroke patients. [1]

Random Forest and Support Vector Machine Model Performance

Per the exploratory data analysis, 34 features and 3406 observations were used to run the Random Forest (RF) and Support Vector Machine (SVM) models. The RF model demonstrated excellent performance (Accuracy 82%) with all 34 features. With different features selected using the Pareto principle, 20 were discarded, yet the model achieved 81% accuracy. Additionally, both RF and SVM models exhibited excellent performance (AUC > 0.9), with feature importance revealing the following features as among the most important predictors for each model:

- RF: Anion gap, Heart rate, Prothrombin time, Creatine serum, Respiratory rate, INR, Blood pressure systolic, Blood pressure diastolic, Age, Platelet count, Glucose whole blood, Bicarbonate, Hemoglobin, Hematocrit
- SVM: Anion gap, Age, GCS eye-opening, Heart rate, Hematocrit, Respiratory rate, SpO2 desat limit, Pulmonary disease, Diastolic, Creatine serum

Among them, Anion gap, Heart rate, Creatine serum, Respiratory rate, Age, Hematocrit, Bicarbonate, and Hemoglobin were identified as the most influential features in predictive models.

Conclusion

Based on the performance of both RF and SVM models compared to the referenced study of the XGBoost model, they demonstrate better performance in predicting the 28-day in-hospital mortality for hypertensive ischemic or hemorrhagic stroke patients in the ICU. However, the model's predictions of the most important features were distinct. While there were similar features in vital signs and demographic groups, laboratory tests contradicted each other in the models. Therefore, predicting the 28-day in-hospital mortality of patients with hypertensive ischemic or hemorrhagic stroke requires further analysis, considering more patient conditions, a physiologically plausible medical test range, and utilizing more data resources.

References

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