Advanced Risk Stratification of Venous Thromboembolism in Critically Ill Patients

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Venous Thrombembolism (VTE) is a preventable disease that is highly problematic in intensive care unit (ICU) settings. With a real-time assessment of VTE risk, physicians will be able to better determine next-steps-of-care to patients at risk for developing VTE.

Background

VTE encompasses two medical complications, Deep Vein Thrombosis (DVT) and Pulmonary Embolism (PE). In 2008, VTE was estimated to account for over 100,000 deaths per year in the US. VTE can be caused by surgery, trauma, or prolonged bed rest, thus putting all patients in an ICU setting at risk for developing a thrombus. Furthermore, for all patients who have symptoms of VTE, only 25% of symptomatic patients actually have a thrombus, making the disease difficult to distinguish from common symptoms patients experience in the ICU. The most effective treatment and prophylaxis for VTE is to administer heparin, which comes with a serious risk of fatal bleeding.

There is currently no standard risk assessment model for VTE within a critical care setting. Despite standard mechanical and pharmacologic prophylaxis, almost 10% of surgical ICU patients develop a VTE. Moreover, diagnosis of VTE is typically at the late stages as the onset of the disease is often asymptomatic. The current diagnostic approach is dependent on patient reported symptoms as well as physiologic parameters, and many available diagnostic tools such as the Modified Wells Score are not sensitive enough for this critically ill population, motivating the need for a new risk assessment tool.

Defined Patient Cohort

All patients are cataloged in the Johns Hopkins Anesthesiology and Critical Care Unit Access Query Interface database containing a total of 10,803 patients. Positive VTE patients are identified via respective ICD10 codes for new acute DVT and PE. Patients with VTE ICD-10 codes present on admission were considered to have a past history of VTE. This resulted in a PE cohort of 138 patients and a DVT cohort of 195 patients.

Methods

Demographic data was aggregated such that categorical data was one hot encoded. Real time data was windowed at the beginning of the ICU visit to establish a baseline measurement of vitals and then compared to vital sign data once VTE was confirmed. Because the time of diagnosis was not provided, we estimated the time of a VTE diagnosis to be the time of ultrasound scan or CT with IV contrast that occurred within 24 hours prior to heparin treatment.

Need Statement

Venous Thromboembolism (VTE) is a preventable disease that is highly problematic in intensive care unit (ICU) settings. With a real time assessment of VTE risk, physicians will be able to better determine next-steps-of-care to patients at risk for developing VTE.

Feature Importance GLM DVT

Obstructive Pulmonary Disease
Cardiac Catheter
Cardiac Surgery
Islander
Cancer
DVT History

Feature Importance GLM PE

Obstructive Pulmonary Disease
Cardiac Catheter
Cardiac Surgery
Islander
Cancer
Ophthalmology

Features of Significance

Our model determined the most significant features in determining VTE likelihood within these models. The data was split into testing and training groups (80:20). The testing group underwent three-fold cross validation. To make up for the smaller sample size, positive patients were upsampled twice.

Several models were tested: Random Forest (RF), Generalized Linear Model (GLM), and Gradient Boosting Model (GBM), of which the GLM model performed with the least overfitting.

Model Performance

<table>
<thead>
<tr>
<th></th>
<th>PE</th>
<th>DVT</th>
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<tbody>
<tr>
<td>Sensitivity</td>
<td>0.8462</td>
<td>0.722</td>
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<tr>
<td>Specificity</td>
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<td>0.5556</td>
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<td>Positive Predictive Value</td>
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<tr>
<td>Negative Predictive Value</td>
<td>0.6364</td>
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</table>

Future Directions

In this project, an unbiased model for VTE risk assessment was created. The inclusion of physiological data is expected to increase the performance of the model. This model is based on traditional markers for VTE as well as less conventional vital sign measurements that will improve the timing and specificity of VTE diagnostic tests.

References