Predicting Mortality Risk Associated with Serious Treatable Surgical Complications at the University of Virginia Health System.

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Abstract - **This study focuses on predicting the risk of occurrence of serious but treatable complications and subsequent risk of mortality using a patient's preoperative conditions. Serious treatable complications include deep vein thrombosis/ pulmonary embolism, pneumonia, sepsis, and shock/cardiac arrest. These complications, if not identified and treated in time, can cause lengthened hospital stays, morbidity, and in some cases, mortality. We have modelled the risk of developing complications, and mortality due to complications using a hierarchical prediction approach. In the first level of the hierarchy, extreme gradient boosted trees with cost sensitive weighting was used to model the risk of each complication and to identify the factors responsible for each type of complication. In the second level, similar statistical methods were used but on a smaller population set of patients, specifically those who developed one or more complications, to predict the risk of mortality. In our population of 32,202 patients, 963 developed one of the complications of interest, and of those with complications 174 died. Our predictions for sepsis, pneumonia, cardiac shock, and deep vein thrombosis/ pulmonary embolism, resulted in mean AUC values of 0.815, 0.935, 0.854, and 0.879 respectively. When making mortality predictions we achieved a mean AUC of 0.921. A propensity score analysis of patients who were predicted to be low risk but actually developed a complication was also performed. The framework proposed in this study provides hospitals with a way to more closely examine patient data regarding quality metrics by enabling them to identify patient borne risks before surgical procedures are performed.**

Index Terms – Gradient Boosted Trees, Mortality Risk Predictions, Propensity Score Matching, Surgical Complications.

INTRODUCTION

Developing a complication following surgery is a very serious event which can lead to an increased risk of mortality. Due to the severity of outcomes attributed to surgical complications, the Agency for Healthcare Research and Quality (AHRQ) has created a set of Patient Safety Indicators (PSI) which "hospitals can use to identify potential adverse events that might need further study" [1]. One such indicator is Patient Safety Indicator 04 (PSI-04), which is defined as the death rate among surgical inpatients with serious treatable complications [2]. Serious treatable complications include deep vein thrombosis/ pulmonary embolism (DVT/ PE), pneumonia, sepsis, shock/cardiac arrest or gastrointestinal hemorrhage/acute ulcer [2]. These complications, if not identified and treated in time, can cause lengthened hospital stays, morbidity, and in some cases, mortality. The complications covered under PSI-04 are particularly concerning because they occur relatively infrequently among the general surgical patient population, but they account for a significant number of surgical mortalities. A review of the Participant Use Data File (PUF) from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) shows that PSI-04 complications occurred in approximately 4% of surgical cases nationally from 2011 to 2014, but they accounted for about 27% of post-surgical deaths in the same duration.

Fully understanding what drives the risk of a patient developing one of these complications can aid in improving decisions about how to treat patients within a hospital setting. Predictive modelling can be a very effective tool in this risk assessment, which ultimately helps hospitals provide better post-surgical care for patients, reduces the risk of mortality after surgery, and enables improved decision making about how a patient should be treated.

The University of Virginia (UVa) Health System Quality and Performance Improvement (QPI) Department wanted to develop a methodology to understand which of their patients were at risk of being affected by a PSI-04 complication, and how these complications affect mortality. The UVa Health System faces similar proportions of PSI-04 complications in their surgical population as on the national scale. About 3% of their patients develop a complication and 27% of their surgical deaths involve one of these complications. To determine a patient's risk associated with PSI-04 complications, we developed a series of models using regularized gradient boosted trees to predict a patient's likelihood of developing a complication, and their subsequent risk of mortality.

As with any modelling task, we had to take measures to address the issue of model misclassification. In the medical setting misclassifications can be particularly concerning because the cost of a false negative, or a patient who appears