Development and Validation of a Machine Learning Model to Predict Postoperative Morbidity and Mortality of Patients with COVID-19 who Underwent Major Surgery

Sean P McDermott MD [1,2], Leming Zhou PhD DSc [2], A. Murat Kaynar MD MPH [1,3]

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University of Pittsburgh

1. Department of Anesthesiology and Perioperative Medicine, University of Pittsburgh Medical Center, Pittsburgh, PA
2. Department of Health Information Management, School of Health and Rehabilitation Sciences, University of Pittsburgh, Pittsburgh, PA;
3. Department of Critical Care Medicine, University of Pittsburgh, Pittsburgh, PA

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INTRODUCTION

Problem: Active coronavirus disease (COVID-19) increases the risk of morbidity and mortality after surgery… if these patients need surgery, how best to determine who is high risk (delay surgery and optimize), and who is not (proceed with surgery) in objective way?

Goal: Predict postoperative outcomes based on preoperative features with machine learning algorithms, investigate risk factors

METHODS

Data Source: American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) - 2021 and 2022 datasets:

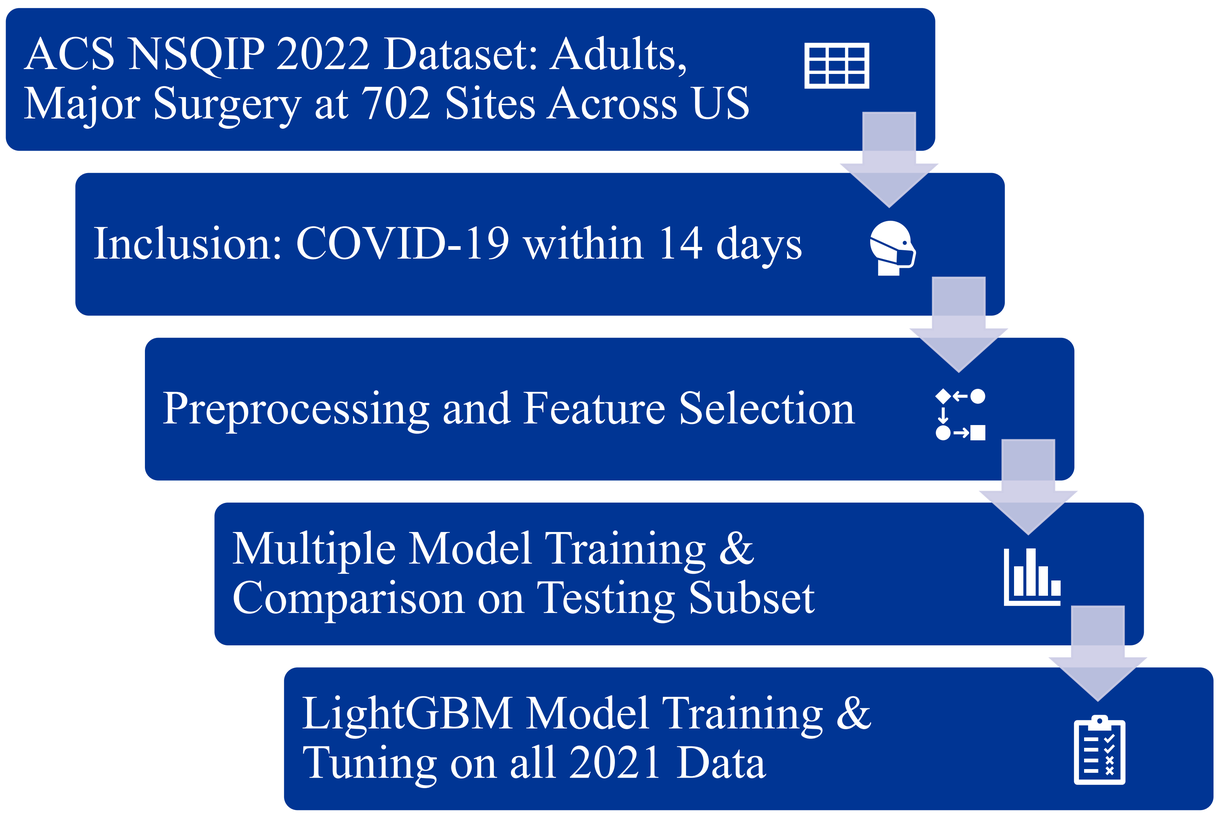
- Inclusion: COVID-19 within 0-14 days prior to surgery
  - 2022 (model development): 10,613 patients with COVID-19
  - 2021 (model validation): 5,269 patients with COVID-19

Outcome: Either 30-day mortality or major morbidity:
Pneumonia, prolonged ventilation, pulmonary embolism, myocardial infarction, cardiac arrest, renal failure, venous thrombosis

ML Models: Naïve Bayes, logistic regression, SVM, LightGBM, XGBoost, k-NN, perceptron, TabNetClassifier (pytorch)

Pre-processing: Imputation, scaling, one-hot encoding, SMOTE oversampling, feature selection by clinical significance

- 153 features included, excluded all postoperative information



RESULTS

- Mortality:
  5.2% with COVID-19 vs. 0.9% without in 2022 – significant ($p < 0.05$)
  7.2% with COVID-19 vs. 1.0% without in 2021 – significant
- Composite Outcome:
  11.8% with COVID-19 vs. 3.0% without in 2022 – significant
  17.2% with COVID-19 vs. 3.2% without in 2021 – significant

Testing Multiple Models (only using 2022 data):

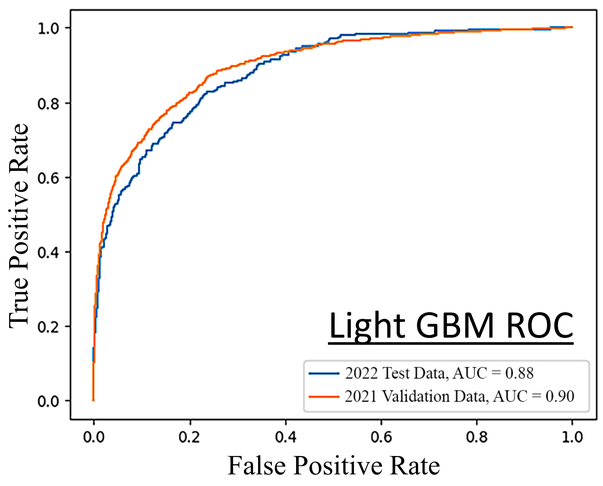
	Complement Naïve Bayes	K-Nearest Neighbors	LightGBM	Logistic Regression	Multilayer Perceptron	Random Forest	Support Vector Machine	XGBoost	TabNet
Accuracy	0.794	0.726	0.858	0.812	0.808	0.904	0.835	0.879	0.912
Precision	0.337	0.259	0.433	0.359	0.352	0.644	0.385	0.490	0.720
Recall	0.780	0.716	0.672	0.756	0.748	0.412	0.680	0.612	0.336
AUC	0.876	0.802	0.884	0.880	0.874	0.876	0.863	0.880	0.862
F1 Score	0.471	0.381	0.527	0.486	0.478	0.502	0.492	0.544	0.458

Single model (Light GBM) tuning, then validation on prior year data:

Light-GBM: highly performing above, hyperparameters tuned:

- Trained- all 2022 Data
- Tested- unseen 2021 Data:

Metric	Value
Accuracy	0.84
PPV	0.52
Sensitivity	0.77
Specificity	0.85
F1 Score	0.62
AUC	0.91



Increased Mortality & Morbidity Prediction
Older age
Higher wRVU procedure
ASA Physical Status (PS) Class V
Higher BUN
Higher preoperative INR
Higher weight
Lower serum albumin
Preoperative ventilator support
Preoperative septic shock
Longer operative time
ASA PS IV
Preoperative oxygen support required

Decreased Mortality & Morbidity Prediction
Outpatient status
No preoperative sepsis
ASA PS II
Laparoscopic operative approach

Abbreviations and Notes:
ASA PS – American Society of Anesthesiologists (ASA) Physical Status (PS) Classification: measure of comorbid disease that is associated with perioperative mortality, assigned by Anesthesiologist, ranges from I (healthy) to V (extreme systemic comorbid disease)
BUN – Blood urea nitrogen lab value – measure of renal function
INR – International normalized ratio – measure of liver function & coagulation
wRVU - Work relative value units – measure of complexity of surgical procedure

Statistical significance determined with $p<0.05$

CONCLUSION

- LightGBM - strong performance: validation AUC 0.90, F1 0.62
- Predictive model & features could provide more objective risk stratification: improve high-stakes perioperative decision-making, improve safety, optimize surgical timing, minimize delays of care

NOTES

References:
1. McNelis J, Castaldi M. "The National Surgery Quality Improvement Project" (NSQIP): a new tool to increase patient safety and cost efficiency in a surgical intensive care unit. Patient Saf Surg. 2014 Apr 24;8:19.
2. Knisely A, Zhou ZN, Wu J, Huang Y, Holcomb K, Melamed A, et al. Perioperative Morbidity and Mortality of Patients With COVID-19 Who Undergo Urgent and Emergent Surgical Procedures. Ann Surg. 2021 Jan;273(1):34. ASA and APSF Joint Statement on Elective Surgery/Procedures and Anesthesia for Patients after COVID-19

- No external funding was utilized for this project
- As noted by the American College of Surgeons, "the American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors."
- This study did not meet the regulatory definition of human subjects research, as the data were not collected specifically for this study and were fully anonymized. The University of Pittsburgh Institutional Review Board (IRB) confirmed that review was not required.