Interpretable machine learning-based predictive modeling of patient outcomes following cardiac surgery

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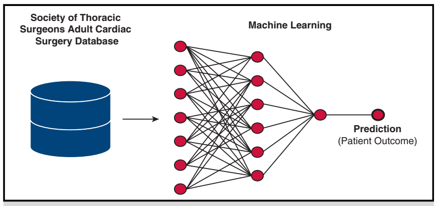
ABSTRACT

Background: The clinical applicability of machine learning predictions of patient outcomes following cardiac surgery remains unclear. We applied machine learning to predict patient outcomes associated with high morbidity and mortality after cardiac surgery and identified the importance of variables to the derived model's performance.

Methods: We applied machine learning to the Society of Thoracic Surgeons Adult Cardiac Surgery Database to predict postoperative hemorrhage requiring reoperation, venous thromboembolism (VTE), and stroke. We used permutation feature importance to identify variables important to model performance and a misclassification analysis to study the limitations of the model.

Results: The study dataset included 662,772 subjects who underwent cardiac surgery between 2015 and 2017 and 240 variables. Hemorrhage requiring reoperation, VTE, and stroke occurred in 2.9%, 1.2%, and 2.0% of subjects, respectively. The model performed remarkably well at predicting all 3 complications (area under the receiver operating characteristic curve, 0.92-0.97). Preoperative and intraoperative variables were not important to model performance; instead, performance for the prediction of all 3 outcomes was driven primarily by several postoperative variables, including known risk factors for the complications, such as mechanical ventilation and new onset of postoperative arrhythmias. Many of the postoperative variables important to model performance also increased the risk of subject misclassification, indicating internal validity.

Conclusions: A machine learning model accurately and reliably predicts patient outcomes following cardiac surgery. Postoperative, as opposed to preoperative or intraoperative variables, are important to model performance. Interventions targeting this period, including minimizing the duration of mechanical ventilation and early treatment of new-onset postoperative arrhythmias, may help lower the risk of these complications. (J Thorac Cardiovasc Surg 2023;■:1-10)



Machine learning-based predictive modeling of patient outcomes following cardiac surgery.

CENTRAL MESSAGE

Explainable machine learning identified 2 potential targets for intervention to lower the risks of hemorrhage requiring reoperation, venous thromboembolism, and stroke following cardiac surgery.

PERSPECTIVE

Explainable machine learning can identify targetable risk factors to lower morbidity and mortality following cardiac surgery. Machine learning predicted postoperative hemorrhage, venous thromboembolism, and stroke remarkably well. Model performance for the prediction of all 3 complications was driven primarily by postoperative variables related to mechanical ventilation and new-onset arrhythmias.

See Commentary on page XXX.

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A majority of the more than 300,000 cardiac surgeries reported in 2019 to the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (ACSD) were performed using cardiopulmonary bypass (CPB).[1] The extracorporeal bypass circuit activates a systemic inflammatory response that contributes to postoperative coagulopathy and

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Abbreviations and Acronyms

AUC = area under the receiver operating characteristic curve
ACSD = Adult Cardiac Surgery Database
CPB = cardiopulmonary bypass
PFI = permutation feature importance
STS = Society of Thoracic Surgeons
VTE = venous thromboembolism

Scanning this QR code will take you to the table of contents to access supplementary information.

neurocognitive dysfunction, increasing the risk of hemorrhage requiring reoperation, venous thromboembolism (VTE), and stroke.[2-4] Each of these complications is an independent predictor of mortality following cardiac surgery and is associated with higher healthcare utilization and cost.[5] Despite technological advances and improvements in perioperative care, the rates of hemorrhage requiring reoperation and stroke after cardiac surgery have not improved.[6-9]

Machine learning is able to handle and process large volumes and wide varieties of clinical data to improve the quality and automaticity of pattern recognition and has been used to predict patient outcomes after cardiac surgery.[10] A recent meta-analysis of 15 studies revealed that machine learning models consistently and significantly outperformed traditional models in predicting postoperative mortality.[11] The clinical relevance of this superior performance remains unclear, however.[12] No machine learning models have been prospectively validated in cardiac surgery, raising questions about their generalizability, clinical feasibility, and efficacy. We previously applied deep learning, an advanced subset of machine learning based on artificial neural networks, to routinely collected electronic health record data to accurately and reliably predict patient outcomes, including hemorrhage requiring reoperation in real-time after cardiac surgery.[13] The model performed well when externally validated and surpassed standard of care clinical reference tools using traditional biostatistics. To target specific factors for intervention, understanding which variables are important to a machine learning model's predictive capacity is essential.

Modern machine learning models are often characterized as "black boxes" because they are based on a network of billions of parameters not readily explicable or comprehensible to humans.[14] In comparison, traditional biostatistical models can delineate associations simply, often as odds ratios. Permutation feature importance (PFI) dissects machine learning models to elucidate the relative importance of variables to the model, addressing this central interpretability problem that promotes clinician mistrust and is a barrier to adoption.[15] This approach (ie, "explainable artificial intelligence") can provide valuable insight into clinical potential and identify risk factors to target for intervention as we tackle the logistical and regulatory challenges for the real-time application of machine learning in cardiac surgery.[12,15,16]

Our study aim was to use PFI to identify variables and groups of variables important to the performance of a deep learning model developed to predict postoperative hemorrhage requiring reoperation, VTE, and stroke after cardiac surgery requiring CPB (Figure 1). We hypothesized that PFI would identify clinically relevant factors that can be targeted to improve patient outcomes. Our secondary aim was to conduct a misclassification analysis comparing characteristics of patients correctly classified by our model and those misclassified, to study the limitations of the model and internally validate the PFI results.

METHODS

This study was approved by our Institutional Review Board (Lifespan #413818; August 20, 2018) and the STS Participant User File Research Program. We applied for and received data submitted to the STS from participating centers using data collection form version 2.81. The STS ACSD is the largest adult cardiac surgery outcomes registry, containing data for more than 600 variables categorized into preoperative, intraoperative, and postoperative groups from more than 7 million cardiac surgeries performed by surgeons worldwide.[1]

We merged the data files that we received and performed an exploratory data analysis to inform data preprocessing. We systematically cleaned the resulting dataset to minimize the introduction of bias and maximize model performance.[17] Subjects undergoing off-pump cardiac surgery not requiring CPB or missing any of the 3 patient outcomes of interest data were dropped. Overlapping variables and variables with values with <1% variance were dropped. The STS codebook and simple inference were used to determine whether missing data were truly missing or appropriately missing due to branching logic. Finally, variables missing >5% of values were dropped. Testing with higher thresholds (dropping less features) did not improve model performance. For this reason, missing data were not imputed.

We built a deep learning feed forward neural network using TensorFlow, a popular open-source platform for machine learning with an extensive library of machine learning tools. The model consisted of 2 fully connected layers separated by 2 hidden layers, a rectified linear activation function unit commonly used to introduce nonlinearity, and a dropout layer to randomly drop input variables at a rate of 20% during training to prevent overfitting (Figure 2). We randomly split the study dataset into discrete training (80%), testing (10%), and validation (10%) cohorts. Single-class modeling was used to predict the 3 patient outcomes. The model was sequentially trained and tested on the training and testing cohorts, respectively, and the model hyperparameters tuned on the validation cohort to maximize model performance. SMOTE (synthetic minority oversampling technique) was used to overcome the severe class imbalance created by the low prevalence of the 3 patient outcomes of interest, creating a balanced training cohort with an equal number of subjects with and without each of the outcomes of interest.[18] The derived model was assessed using common performance metrics including discrimination (area under the receiver operating characteristic curve [AUC]) and calibration.[19]

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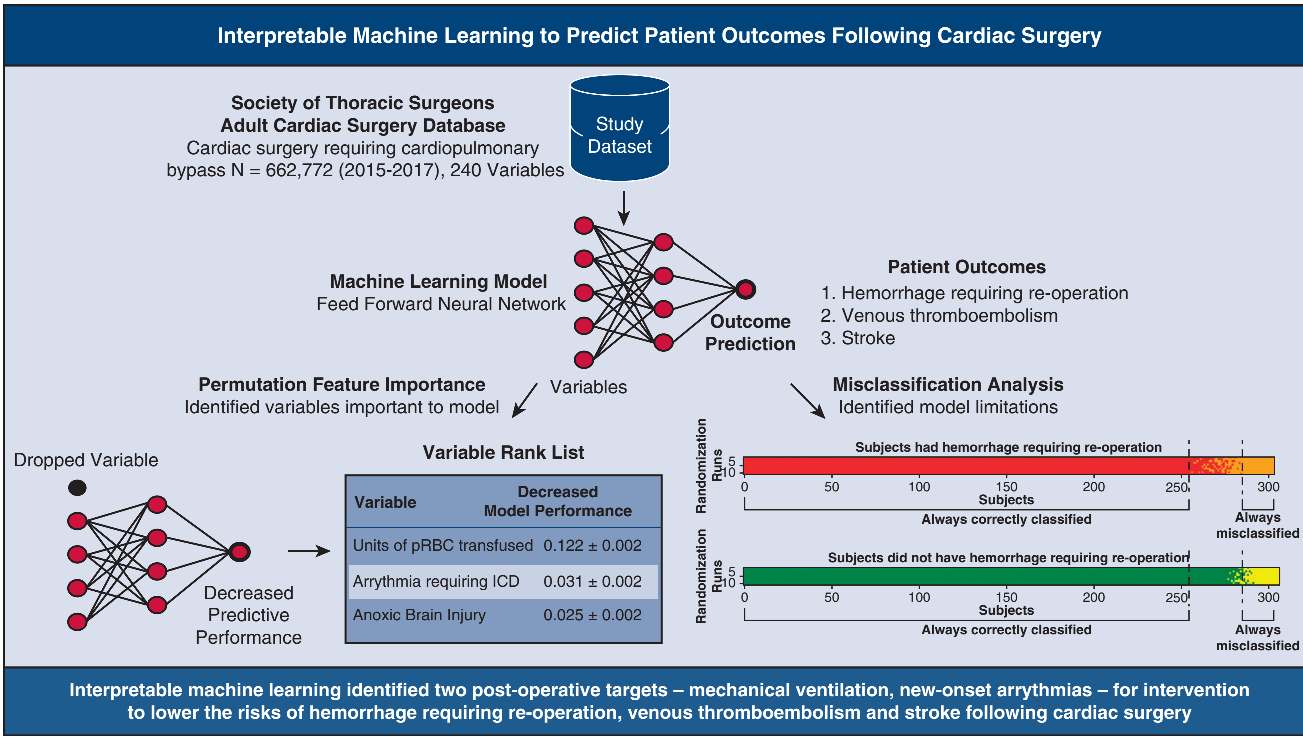

FIGURE 1. Study outline summarizing methods and results. *pRBC*, Packed red blood cells; *ICD*, implantable cardioverter-defibrillator.

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We defined our 3 a priori binary patient outcomes of interest using existing postoperative complication variables within the STS ACSD.[1] Hemorrhage requiring reoperation was defined as mediastinal hemorrhage with or without tamponade requiring reoperation, VTE was defined as deep venous thrombosis or pulmonary embolism, and stroke was defined as an ischemic, hemorrhagic, or embolic stroke.

The model was trained using all variables and tested before and after all values for each variable or perioperative group were randomly permuted in the testing cohort, 1 variable or perioperative group at a time.[20] Permutation rendered the variable or group of variables uninformative. The values were permuted and tested 30 times to determine the mean and standard deviation change in the AUC before and after the permutation. The decrease in model performance after permutation was presented from high to low to create a ranked list of variables and perioperative groups important to model performance for each complication.

The distributions of the values of the variables in subjects always correctly classified were compared to the distributions for subjects always misclassified for the same complication (Figure 3). The distributions within each pair of distributions for each variable were compared and ranked by

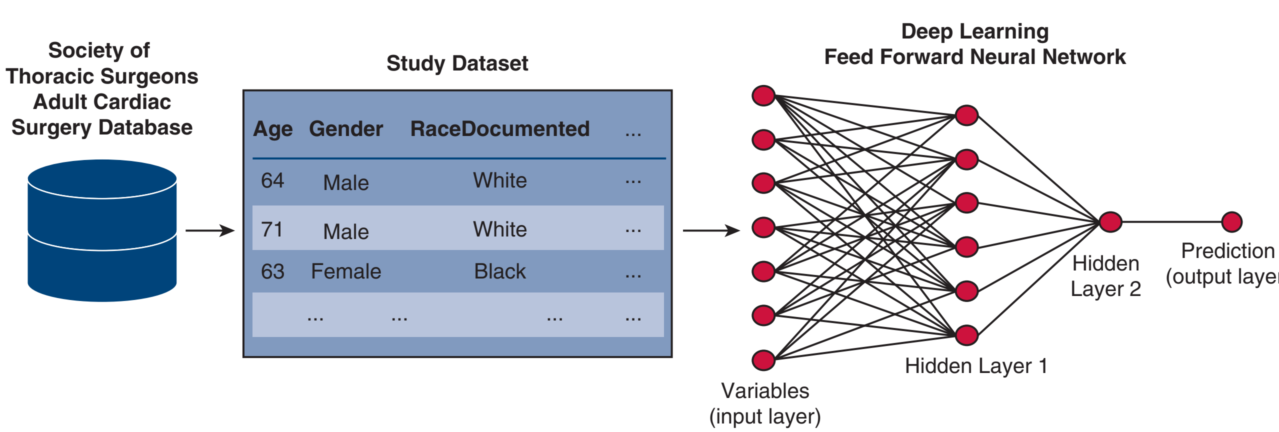

FIGURE 2. Schematic of deep learning feed forward neural network development.

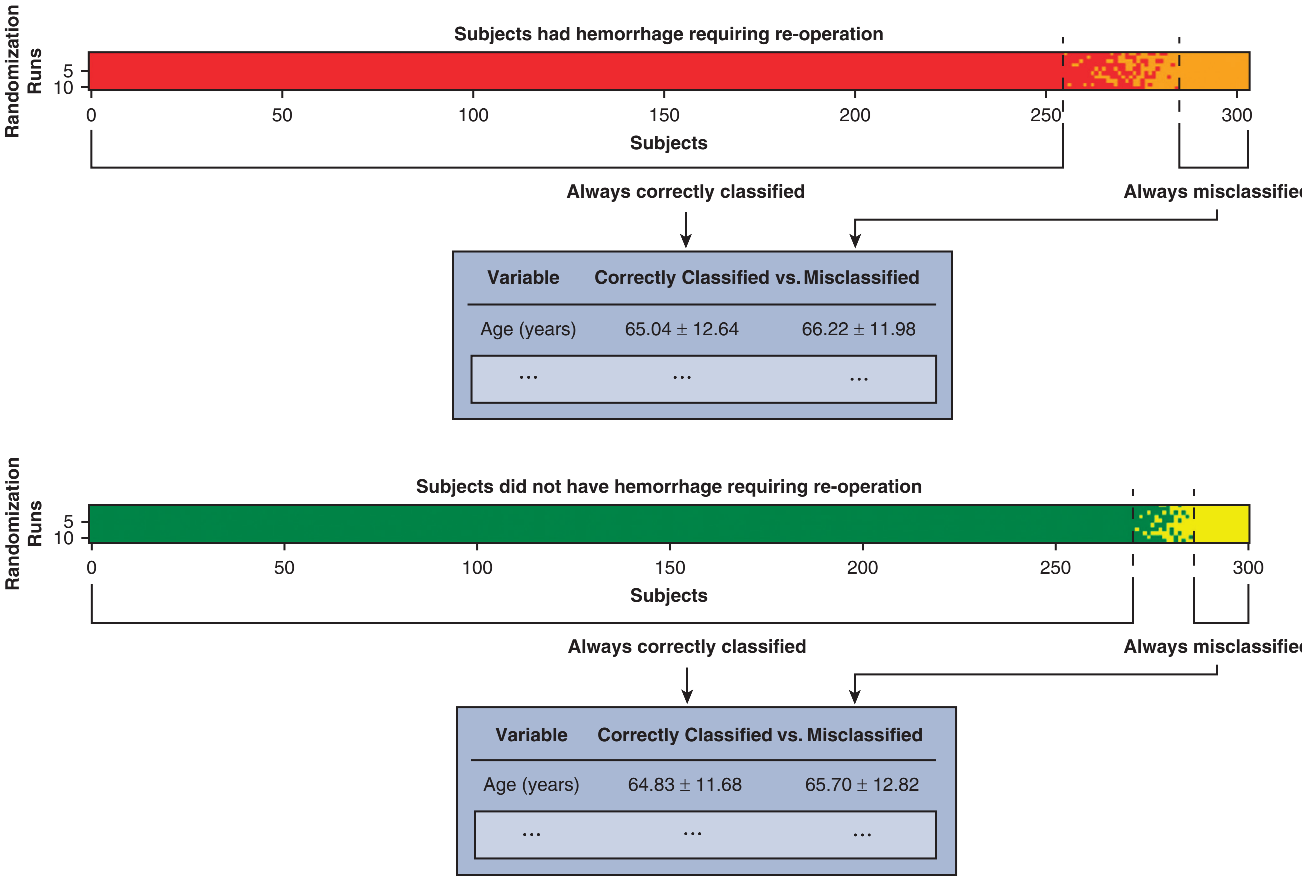

FIGURE 3. Schematic of misclassification analysis. The heatmaps depict the subsets of 300 subjects always correctly classified (*red* and *green*) versus subjects always misclassified (*orange* and *yellow*) by the deep learning feed forward neural network over 10 randomization runs. The characteristics (age) of the subjects always correctly classified versus subjects always misclassified were then compared.

calculating the quadratic-chi distance and the variable means and standard deviations. The Pearson χ^2 test was used to determine statistical significance, which was defined as $P < .05$.

RESULTS

The study dataset comprised 662,772 subjects across 1,080 centers who had undergone cardiac surgery requiring CPB between 2015 and 2017, and 240 variables: 126 preoperative, 67 intraoperative, and 47 postoperative variables (Figure 4). Table E1 lists the characteristics of the subjects in the study dataset. The subjects' mean age was 64.9 years ± 11.8, and the majority were men (69.4%), white (83.5%), and non-Hispanic/Latino (93.3%). The most common cardiac surgery performed was coronary artery bypass graft surgery (65.9%). Outcomes of interest occurred in 2.9% of subjects with postoperative hemorrhage requiring reoperation, 1.2% of those with VTE, and 2.0% of those with stroke. New-onset postoperative atrial fibrillation was the most common complication (26.9%).

The deep learning model performed very well at predicting all 3 complications (Table 1, Figure 5). Backpropagation helped model performance improve over successive epochs, and there was no evidence of model overfitting (Figure E1). The model was best able to predict hemorrhage requiring reoperation, with an AUC of 0.97 (95% CI, 0.97-0.97), followed by VTE (AUC, 0.92; 95% CI, 0.92-0.92) and stroke (AUC, 0.92; 95% CI, 0.92-0.93). Model calibration also was highest for the prediction of hemorrhage requiring reoperation (c = 0.85), followed by VTE (c = 0.79) and stroke (c = 0.75). Notably, the model performed well at predicting all 3 complications for males and females and for all races and ethnicities (Table E2).

Permutation of preoperative and intraoperative groups independently and collectively resulted in only minor reductions in model performance for the prediction of all complications (Figure 6, Table E3). In contrast, permutation of the postoperative group dramatically lowered model performance for all complications. This was confirmed by a perioperative group ablation analysis by training the model only on the postoperative group (dropping preoperative and intraoperative groups). Thus, postoperative variables contributed the most to model performance, whereas preoperative and intraoperative variables contributed minimally. This was also confirmed by variable permutation;

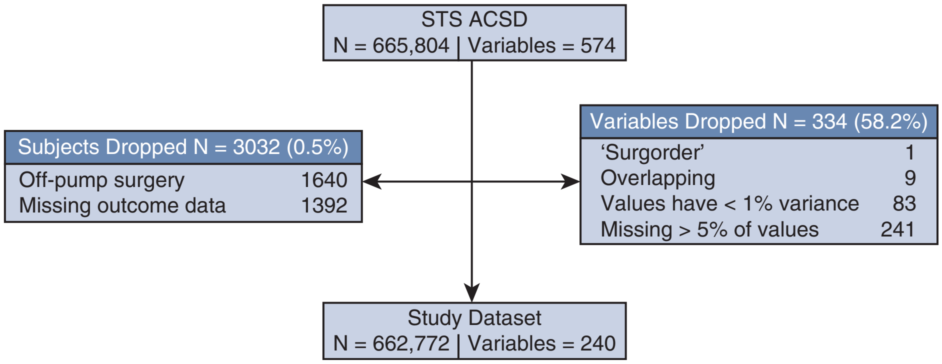

FIGURE 4. Data cleaning: subjects/variables. *STS-ACSD*, Society of Thoracic Surgeons Adult Cardiac Surgery Database.

prediction of all 3 complications was informed primarily by postoperative variables (Figure 7, Tables E4 to E6).

Model prediction of all 3 complications was driven by just a few postoperative variables (Figure 7, Tables E4 to E6). Two of the top 4 variables most important for hemorrhage requiring reoperation were *units of postoperative red blood cells* and *platelets*, ranked first and fourth respectively, with *fresh frozen plasma* ranked eighth. The same 2 variables were most important to model performance for VTE and stroke: *postoperative hospital length of stay* and *new postoperative arrhythmia requiring an implantable cardioverter-defibrillator*, whereas the 2 variables *new postoperative arrhythmia not requiring pacemaker* and *total duration of mechanical ventilation* ranked fourth and sixth for the prediction of VTE and third and fourth for the prediction of stroke. Some variables were important to model performance for the prediction of all 3 complications. *New postoperative arrhythmia requiring an implantable cardioverter-defibrillator* was the second most important variable for the prediction of all 3 complications, and *new postoperative arrhythmia not requiring pacemaker* ranked fifth for hemorrhage requiring reoperation, fourth for VTE, and third for stroke. The variable *total duration of mechanical ventilation* ranked high for all 3 outcomes. Several binary variables were important, with both values of the variable ranked high and the more clinically significant value often ranked higher. For example, *postoperative reintubation* and *not reintubated postoperatively* ranked highly for hemorrhage requiring reoperation (ninth and twelfth, respectively). *No postoperative hemorrhage/emboli due to anticoagulation* were important for VTE, with *no postoperative hemorrhage/emboli due to anticoagulation* ranked higher. Similarly, *new* and *no new onset of postoperative atrial fibrillation* were important for VTE and stroke, with the former ranked higher for both complications.

There was little overall difference between subjects correctly classified and misclassified, as the majority of variables had very short quadratic-chi distances for all 3 complications. (Tables E7 to E9). Misclassified subjects differed the most from those correctly classified by many of the postoperative variables important to model performance, particularly for hemorrhage requiring reoperation. *Total duration of mechanical ventilation* was important to model prediction for all 3 complications. It was the highest-ranked variable for subjects misclassified as having all 3 complications and ranked third and fourth for subjects misclassified as not having VTE and not having stroke, respectively. Unsurprisingly, many of the variables important to model performance for hemorrhage requiring reoperation were related to the transfusion of blood products. The same variables ranked highly for subjects misclassified as having and not having hemorrhage. There were more discrepancies among predictive model performance and variable quadratic chi-distance for VTE and stroke. *New onset of postoperative atrial fibrillation* was important to model performance for the prediction of VTE and stroke but was less important to the model misclassifying subjects as having and not having these 2 complications.

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TABLE 1. Performance of the deep learning feed forward neural network

Postoperative complication	Accuracy	Sensitivity	Specificity	PPV	NPV	F_1 score	Discrimination AUC (95% CI)	Calibration
Hemorrhage requiring reoperation	0.93	0.87	0.93	0.25	0.99	0.39	0.97 (0.97-0.97)	0.85
VTE	0.90	0.69	0.90	0.08	0.99	0.14	0.92 (0.92-0.92)	0.79
Stroke	0.87	0.77	0.87	0.11	0.99	0.19	0.92 (0.92-0.93)	0.75

PPV, Positive predictive value; *NPV*, negative predictive value; *AUC*, area under the receiver operating characteristic curve; *CI*, confidence interval; *VTE*, venous thromboembolism.

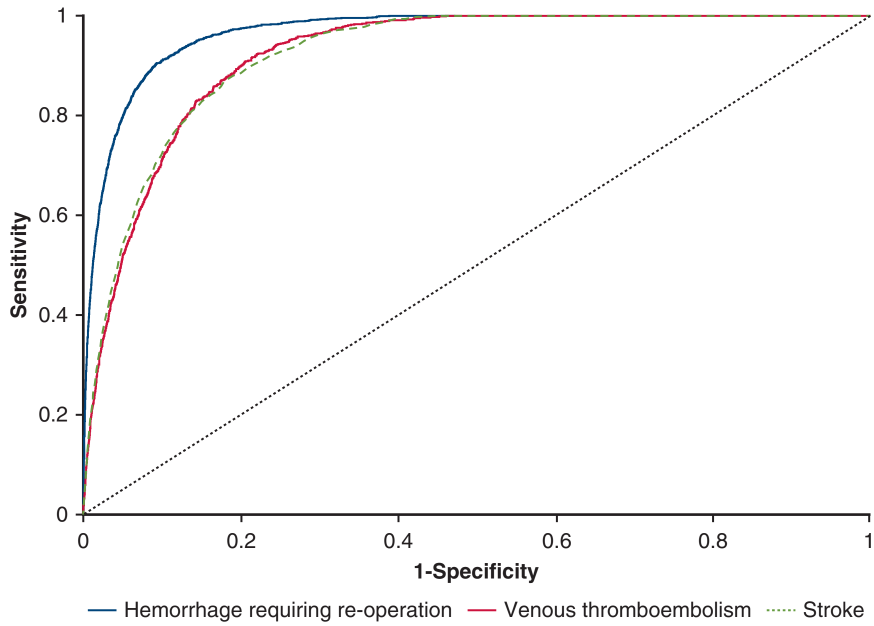

FIGURE 5. Performance of the deep learning feed forward neural network. Area under the receiver operating characteristic curve: hemorrhage requiring reoperation, 0.97 (95% confidence interval [CI], 0.97-0.97); venous thromboembolism, 0.92 (95% CI, 0.92-0.92); stroke, 0.92 (95% CI, 0.92-0.93).

DISCUSSION

We developed a deep learning model to predict 3 significant postoperative complications after cardiac surgery requiring CPB. Overall, model performance was excellent. For the first time, we identified the relative importance of variables and groups of variables to model performance and those that also increased subject misclassification. The postoperative period was the most critical for outcome

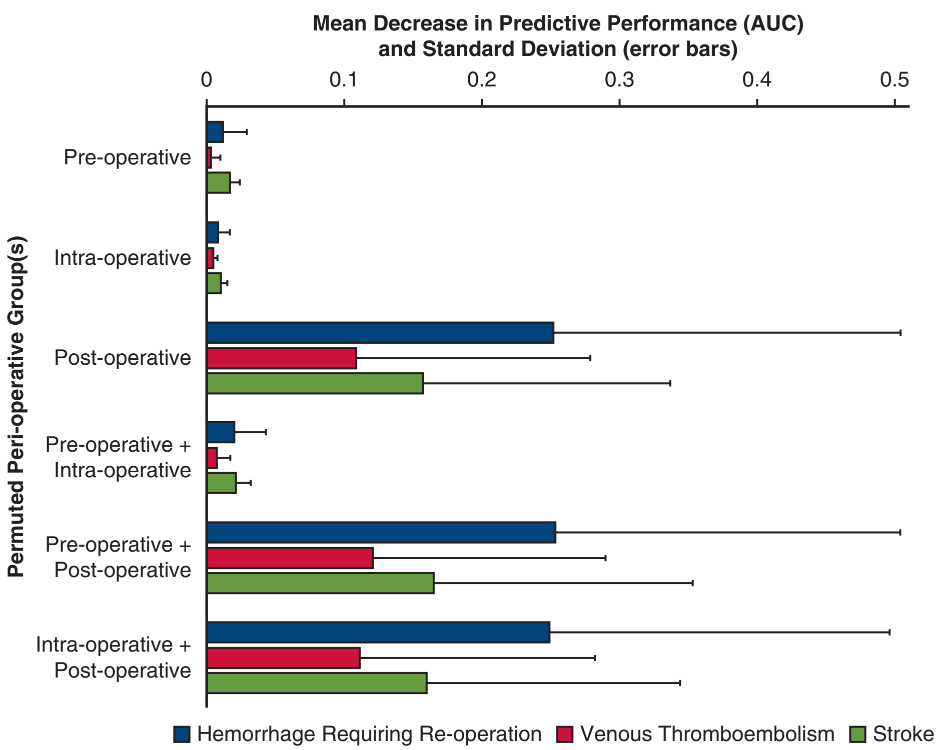

FIGURE 6. Decrease in performance of the deep learning feed forward neural network with perioperative group permutation feature importance for hemorrhage requiring reoperation. *AUC*, Area under the receiver operating characteristic curve.

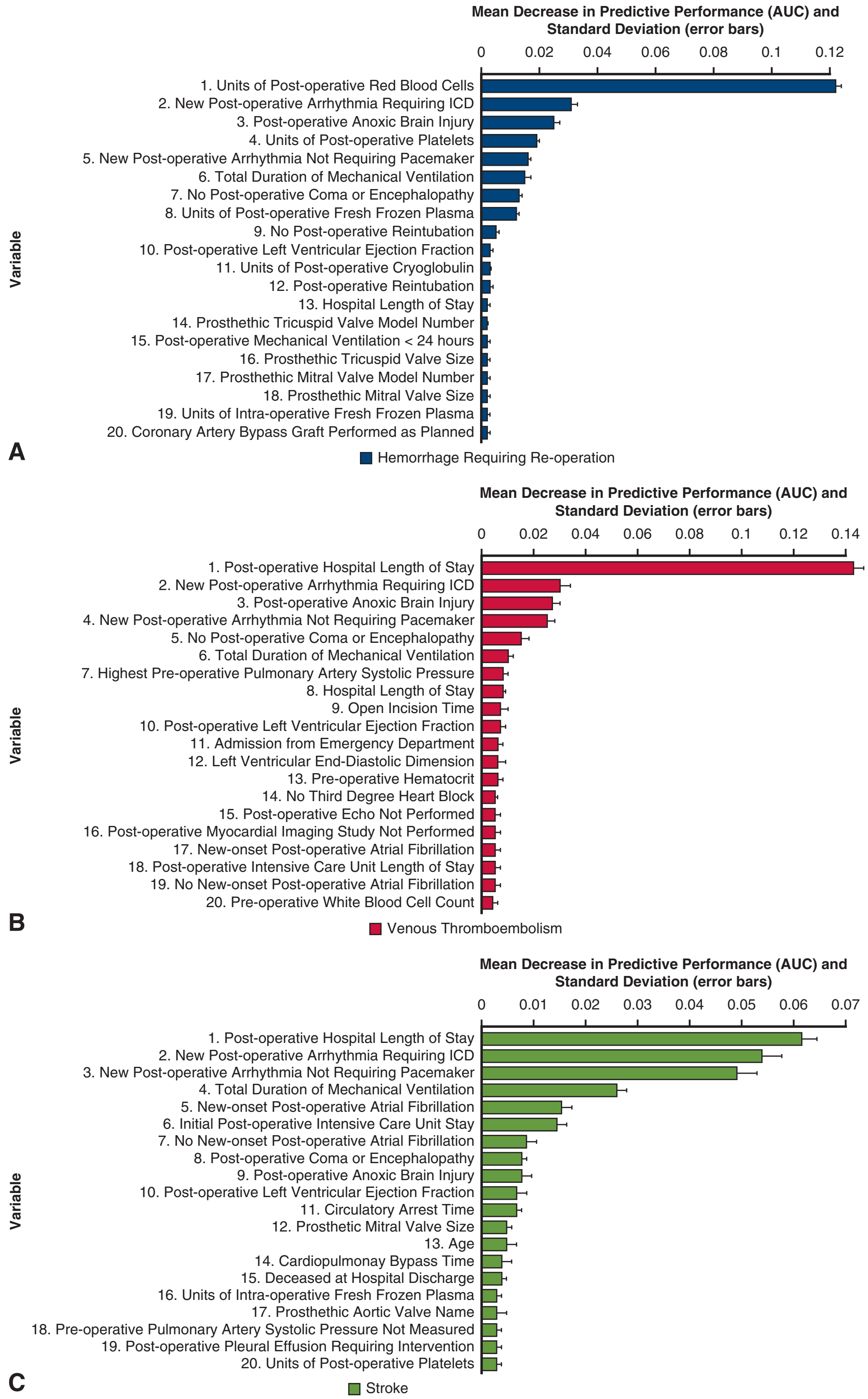

FIGURE 7. Decrease in performance of the deep learning feed forward neural network with variable permutation feature importance for hemorrhage requiring reoperation (A), venous thromboembolism (B), and stroke (C). *AUC*, Area under the receiver operating characteristic curve; *ICD*, implantable cardioverter-defibrillator.

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prediction. Clinically targetable variables, such as duration of mechanical ventilation and new-onset postoperative arrhythmias, emerged as important to model performance and subject misclassification regardless of subject demographics. To date, machine learning has been successfully used to predict patient outcomes after cardiac surgery, but its clinical relevance has remained questionable.[12,16] Our interpretability approach suggests that studies should target the postoperative period, and specifically strategies to reduce the duration of mechanical ventilation and risk of arrythmias, for potential intervention.

Our model generalized well with a similar training performance, suggesting no overfitting. The model performed well across all performance metrics except positive predictive values and resulting F_1 scores. This is expected, given the very low prevalence of all 3 complications, and was confirmed by retraining on a balanced cohort resulting in high positive predictive values and F_1 scores (Table E10). Although the cohort was predominantly male and white, performance was maintained regardless of subject sex, race, and ethnicity. The results of the misclassification analysis revealed minor differences in characteristics between subjects who were correctly classified and those who were misclassified, providing internal validity for the model's reliability and accuracy (Tables E11 to E13). Older subjects had a slightly higher likelihood of being misclassified.

Variable rank lists for the 3 complications only included a fraction of the 240 variables available. Furthermore, permutation of a majority of the ranked variables resulted in a performance drop of almost zero or true zero—the majority of variables were not important to model performance. Our results suggest that a more parsimonious collection of data in large registries could be used, depending on the outcomes of interest. Model performance for all 3 outcomes was driven primarily by several postoperative variables. This included both values of some binary variables with the more clinically significant value often ranked higher (more important). This "clinical logic" is promising and supports the notion that the rule-based logic of machine learning can mimic clinical reasoning. The presence of both values also mirrors how a clinician thinks, weighing both the presence and absence of risk factors to gauge cumulative risk and make clinical decisions. This also explains why misclassified subjects differed the most from those correctly classified by many of the postoperative variables important to model performance. The model seems to be relying heavily on these variables to make predictions, which most of the time resulted in the correct prediction.

Our results suggest that the postoperative period after cardiac surgery is the most critical. This makes intuitive sense; a predictive model ideally should integrate data up to the occurrence of the outcome of interest, and exclude data following the outcome. This may be especially relevant for late complications, which can be delayed in presentation after cardiac surgery and can have distinct risk factors.[21] Delayed stroke after cardiac surgery is associated with new-onset postoperative atrial fibrillation, whereas early stroke is associated with intraoperative aortic manipulation.[22] A majority of existing studies and risk calculators include only preoperative and intraoperative variables or even just preoperative variables. The STS Short-Term Risk Calculator estimates a patient's risk of postoperative complications including stroke, and is based almost entirely on preoperative variables.[6,23,24] Although designed to estimate a patient's risk of postoperative complications before surgery, our results suggest that the risk calculator potentially excludes important postoperative risk factors preceding the complication and underestimates risk. To this point, a validation study demonstrated that the risk calculator consistently underestimated postoperative mortality in 2 cohorts.[25] Despite advances in care, the risk of hemorrhage and stroke after cardiac surgery have not improved.[6-9] Although our results require prospective validation, interventions specifically targeting the postoperative factors that we identified may help reduce the risk of these complications.

Preoperative and intraoperative variables were less important to model performance for all complications. This was confirmed by performing a perioperative group ablation analysis, sequentially ablating (dropping) perioperative groups of variables with similar results. Data for patients not offered cardiac surgery because they are too high risk are not included in the STS ACSD. Thus, the preoperative group of variables may be less important to a model predicting postoperative complications because of selection bias. Furthermore, patients who undergo cardiac surgery also are routinely optimized before surgery whenever possible.[26] As our cohort is fairly modern (2015-2017), current approaches to preoperative care based on risk factors identified in historical cardiac surgery cohorts may be adequate to minimize postoperative complications.[23,24] Including data on the elective or emergent nature of the surgery would help ascertain whether optimization for surgery impacted the importance of perioperative factors; however, values for this variable (*status*) were missing too often in our study dataset for this secondary analysis to be performed. Nevertheless, given that the STS is the largest available registry and considering the multiple approaches that we used to assess validity, we submit that our results are generalizable to adults who undergo cardiac surgery and require CPB.

Some of the variables important to model performance are known risk factors for our postoperative complications of interest, adding face validity. Several variables that capture CPB duration and left ventricular function contributed to our VTE and stroke models and have been previously linked to these outcomes in observational studies.[27-29]

Cardiac arrhythmias including atrial fibrillation are common after cardiac surgery and increase the risk of postoperative hemorrhage and VTE.[30] Atrial fibrillation increases the risk for stroke by 2- to 4-fold including during the postoperative period. *New-onset postoperative atrial fibrillation* improved the prediction of VTE and stroke, and the related variables *postoperative arrhythmia requiring* or *not requiring a pacemaker and implantable cardioverter-defibrillator* improved the prediction of all 3 complications in our study. Variables related to mechanical ventilation contributed to model performance for all 3 complications. Prolonged mechanical ventilation for >12 hours is known to increase morbidity and mortality; early extubation within 6 hours is associated with a lower rate of postoperative complications after cardiac surgery.[31,32] Although the risks of mechanical ventilation may be attributable to related factors, including immobilization (which increases the risk of VTE) and prolonged exposure to sedatives and analgesics, mechanical ventilation in and of itself may lead to operative complications.[33,34] Of note, there was a consistent signal between variables related to mechanical ventilation and hemorrhage requiring reoperation, VTE, and stroke. In experimental models, mechanical ventilation alone causes systemic coagulopathy and cerebral dysfunction.[35,36] Preventive strategies and interventions targeting new-onset postoperative arrythmias and liberation from mechanical ventilation after cardiac surgery may improve surgical outcomes.

Our study has several strengths. It marks the first time that this interpretability approach and misclassification analysis have been used to analyze a deep learning model developed to predict postoperative complications after cardiac surgery in the largest available dataset to date. We intentionally chose the multicenter, multinational STS ACSD with its large number of variables and outcomes standardized across centers and categorized by STS to facilitate our methods. The resulting deep learning model performed remarkably well across all demographics. In addition to our PFI and ablation analysis, we also performed a Shapley additive explanations (SHAP) analysis and identified remarkably similar features driving model performance (data not shown), further validating our findings.[37]

Our study has some limitations. First, the study dataset included a large number of derived variables (eg, *units of postoperative red blood cells*), some of which were found to be important. This is likely a consequence of or directly related to the complications themselves, thus artificially boosting model performance via reverse causation, although this provides validation for the PFI findings. For example, the prediction of hemorrhage requiring reoperation was most informed by variables related to blood transfusion. Obviously, patients who have bleeding requiring reoperation are more likely to require postoperative blood products. Second, the STS ACSD lacks timed data and outcomes that would have allowed modeling using only data preceding the postoperative complications – including postoperative data preceding the complications – limiting reverse causation. Finally, PFI may artificially lower variable importance. When variables are permuted, the model may infer some or all of the information missing from related variables, potentially altering the rank order of the PFI rank lists.

Our study illustrates the potential of the interpretability approach applied to machine learning to predict important patient outcomes after cardiac surgery requiring CPB. Our results demonstrate that model performance for the prediction of hemorrhage requiring reoperation, VTE, and stroke was driven primarily by several postoperative variables, notably postoperative arrythmias and mechanical ventilation. These key clinical factors could be targeted for future study and intervention to improve patient outcomes.

DATA AVAILABILITY

Contact the Society of Thoracic Surgeons Participant User File Research Program to request data from the Adult Cardiac Surgery Database used in this study. The programming code used for this study is available upon request.

Conflict of Interest Statement

D.B. receives research support from and consults for LivaNova; has served medical advisory boards for Abiomed, Xenios, Medtronic, Inspira and Cellenkos; is the President-elect of the Extracorporeal Life Support Organization (ELSO) and the Chair of the Executive Committee of the International ECMO Network (ECMONet). C.E.V. has served as a consultant for Regeneron, Merck, and Janssen, outside of the submitted work. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: explainable machine learning, Society of Thoracic Surgeons Adult Cardiac Surgery Database, adult cardiac surgery, patient outcomes, hemorrhage requiring reoperation, venous thromboembolism, stroke

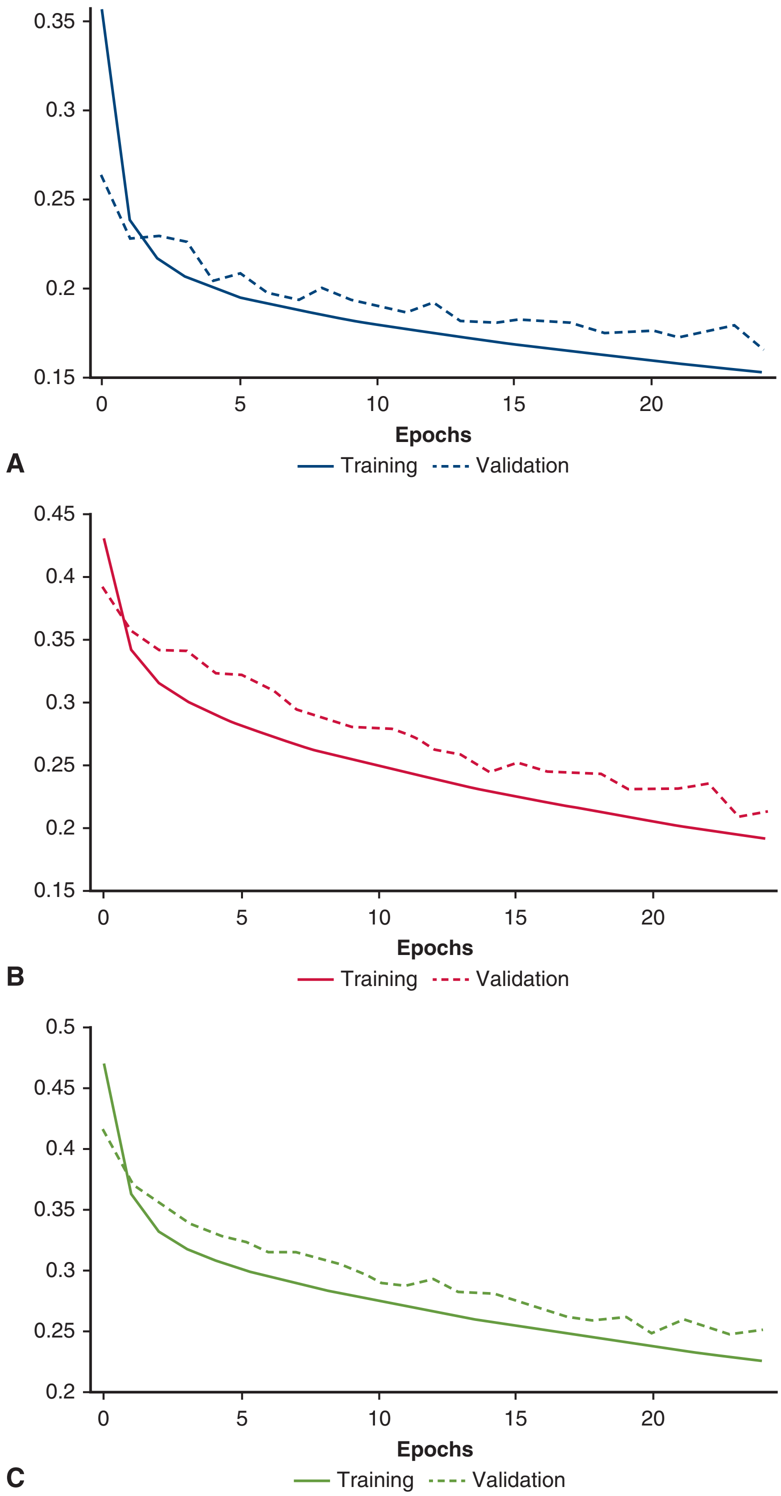

FIGURE E1. A, Training and validation loss curves for deep learning model prediction of hemorrhage requiring reoperation. B, Training and validation loss curves for deep learning model prediction of venous thromboembolism. C, Training and validation loss curves for deep learning model prediction of stroke.

TABLE E1. Characteristics of subjects in the study dataset (N = 662,772)

Characteristic	Value
Demographics	
Age, y, mean ± SD	64.9 ± 11.8
Male sex, n (%)	459,864 (69.4)
Race, n (%)	
White	553,369 (83.5)
Black/African American	53,228 (8.0)
Asian	18,741 (2.8)
American Indian/Alaskan	3706 (0.6)
Hawaiian/Pacific Islander	2905 (0.4)
Other	21,179 (3.2)
Ethnicity	
Hispanic or Latino, n (%)	44,247 (6.7)
Body surface area, m^2, mean ± SD	2.0 ± 0.3
Comorbidities, n '(%)	
Hypertension	553,461 (83.5)
Hyperlipidemia	518,403 (78.2)
Tobacco abuse	391,678 (59.1)
Diabetes mellitus	260,101 (39.2)
Cerebrovascular disease	131,934 (19.9)
Peripheral artery disease	83,094 (12.5)
Liver disease	25,808 (3.9)
End-stage renal disease on dialysis	19,181 (2.9)
Preoperative medications, n (%)	
Antiplatelet (within 5 d)	19,696 (3.0)
Aspirin (within 5 d)	449,587 (67.8)
Anticoagulation (within 48 h)	218,686 (33.0)
Glycoprotein IIb/IIIa inhibitors (within 24 h)	6193 (0.9)
Coumadin (within 24 h)	5691 (0.9)
Factor Xa inhibitors (within 24 h)	2706 (0.4)
Thrombin inhibitors (within 24 h)	2822 (0.4)
Thrombolytics (within 48 h)	1174 (0.2)
Operative characteristics	
Circulatory arrest, n (%)	23,371 (3.5)
Total circulatory arrest time, min, mean ± SD	32.5 ± 27.3
Cardiopulmonary bypass time, min, mean ± SD	114.4 ± 57.1
Cross-clamp time, min, mean ± SD	83.8 ± 43.0
Robot-assisted, n (%)	4322 (0.7)
Extubated in the operating room, n (%)	10.835 (1.6)
Surgery performed, n (%)	
Coronary artery bypass graft surgery	437,080 (65.9)
Valve surgery	274,575 (41.4)
Other cardiac procedure	113,074 (17.1)
Other cardiac procedure, aortic	52,124 (7.9)
Ventricular assist device implanted or removed	13,132 (2.0)
Intraoperative blood products	
Transfused blood products, n (%)	248,025 (37.4)
Red blood cell units, mean ± SD	2.0 ± 2.5
Fresh frozen plasma units, mean ± SD	1.3 ± 2.2

(Continued)

TABLE E1. Continued

Characteristic	Value
Platelet units, mean ± SD	1.3 ± 2.1
Cryoprecipitate units, mean ± SD	0.7 ± 2.4
Mechanical circulatory support, n (%)	
Intra-aortic balloon pump	51,785 (7.8)
Catheter based assist device used	2828 (0.4)
Extracorporeal membrane oxygenation	5348 (0.8)
Ventricular assist device	9815 (1.5)
Postoperative blood products	
Transfused blood products, n (%)	240,680 (36.3)
Red blood cell units, mean ± SD	3.0 ± 4.6
Fresh frozen plasma units, mean ± SD	1.0 ± 2.7
Platelet units, mean ± SD	0.8 ± 2.2
Cryoprecipitate units, mean ± SD	0.4 ± 1.7
Postoperative complications, n (%)	
Hemorrhage requiring reoperation	19,109 (2.9)
Venous thromboembolism	7737 (1.2)
Stroke	12,935 (2.0)
Other postoperative complications, n (%)	
New-onset atrial fibrillation	178,576 (26.9)
Rhythm disturbance requiring device implantation	24,590 (3.7)
Renal failure	22,771 (3.4)
Pneumonia	22,051 (3.3)
Prolonged mechanical ventilation >24 h	83,075 (12.5)
Pleural effusion requiring drainage	34,004 (5.1)
Cardiac arrest	16,228 (2.4)
Sepsis	9718 (1.5)
Surgical site infection (within 30 d of operation)	8592 (1.3)
Hospitalization	
Extubated in operating room, n (%)	10,835 (1.6)
Reintubated during hospital stay, n (%)	32,725 (4.9)
Postoperative duration of mechanical ventilation, h, mean ± SD	26.3 ± 92.0
Intensive care unit length of stay, h, mean ± SD	84.9 ± 130.0
Post-operative length of stays, d, mean ± SD	8.2 ± 8.0
Length of stay, d, mean ± SD	10.7 ± 29.5
Hospital mortality, n (%)	26,574 (4.0)

SD, Standard deviation.

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TABLE E2. Performance of the deep learning model for available demographics

Demographic cohort	AUC (95% CI)
Hemorrhage requiring reoperation	
Male	0.97 (0.96-0.97)
Female	0.96 (0.96-0.97)
White	0.97 (0.96-0.97)
Black/African American	0.95 (0.94-0.95)
Asian	0.97 (0.96-0.97)
Other race	0.97 (0.96-0.98)
Hispanic or Latino	0.97 (0.96-0.97)
Non-Hispanic or Latino	0.97 (0.96-0.97)
Venous thromboembolism	
Male	0.93 (0.92-0.93)
Female	0.91 (0.90-0.92)
White	0.92 (0.92-0.93)
Black/African American	0.89 (0.88-0.91)
Asian	0.94 (0.92-0.96)
Other race	0.92 (0.90-0.95)
Hispanic or Latino	0.92 (0.90-0.93)
Non-Hispanic or Latino	0.92 (0.92-0.92)
Stroke	
Male	0.93 (0.92-0.93)
Female	0.91 (0.90-0.91)
White	0.92 (0.92-0.93)
Black/African American	0.91 (0.89-0.92)
Asian	0.91 (0.89-0.94)
Other race	0.92 (0.90-0.94)
Hispanic or Latino	0.92 (0.91-0.93)
Non-Hispanic or Latino	0.92 (0.92-0.92)

AUC, Area under the receiver operating characteristic curve; *CI*, confidence interval.

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TABLE E3. Decrease in predictive performance of the deep learning model with perioperative group permutation

Permuted perioperative group	Decrease in performance, AUC, mean ± SD		
	Hemorrhage requiring reoperation	VTE	Stroke
Preoperative	0.01 ± 0.02	0.00 ± 0.01	0.02 ± 0.01
Intraoperative	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01
Preoperative + intraoperative	0.02 ± 0.02	0.01 ± 0.01	0.02 ± 0.01
Postoperative	0.25 ± 0.25	0.11 ± 0.17	0.16 ± 0.18
Preoperative + postoperative	0.25 ± 0.25	0.12 ± 0.17	0.17 ± 0.19
Intraoperative + postoperative	0.25 ± 0.25	0.11 ± 0.17	0.16 ± 0.18

AUC, Area under the receiver operating characteristic curve; *SD*, standard deviation; *VTE*, venous thromboembolism.

TABLE E4. Decrease in predictive performance of the deep learning model with variable permutation for hemorrhage requiring reoperation

Rank	Permuted variable	Decrease in performance, AUC, mean ± SD
1	BdRBCU	0.122 ± 0.002
2	CRhythmDis_2	0.031 ± 0.002
3	CNComaEnceph_2	0.025 ± 0.002
4	BdPlatU	0.019 ± 0.001
5	CRhythmDis_4	0.016 ± 0.001
6	logVentHRS	0.015 ± 0.002
7	CNComaEnceph_1	0.013 ± 0.001
8	BdFFPU	0.012 ± 0.001
9	ReIntub_0.0	0.005 ± 0.001
10	PopEF	0.003 ± 0.001
11	BdCryoU	0.003 ± 0.000
12	ReIntub_1.0	0.003 ± 0.001
13	LOS	0.002 ± 0.001
14	VSTrIm	0.002 ± 0.000
15	CPVntLng_0.0	0.002 ± 0.001
16	VSTrImSz	0.002 ± 0.001
17	VSMiIm	0.002 ± 0.001
18	VSAoImSz	0.002 ± 0.001
19	IBdFFPU	0.002 ± 0.001
20	OpCAB_3	0.002 ± 0.001
21	CreatLst	0.001 ± 0.001
22	IbdPlatU	0.001 ± 0.001
23	InfEndo_0.0	0.001 ± 0.000
24	IVDrugAb_4.0	0.001 ± 0.000
25	VDTr_0.0	0.001 ± 0.000
26	AortProcDesProx_0	0.001 ± 0.000
27	Region_GRLAKES	0.001 ± 0.000
28	AortProcTEVAR_1,2,3	0.001 ± 0.000
29	VDInsufT_3.0	0.001 ± 0.000
30	AortProcAsc_1.0	0.001 ± 0.000
31	AortProcHemi_1.0	0.001 ± 0.000
32	ADLesTAneur_1.0	0.001 ± 0.000
33	AortaDisease_1.0	0.001 ± 0.000
34	CanArtStAx_1.0	0.001 ± 0.000
35	CanArtStAx_0.0	0.001 ± 0.000
36	COpPlndDelay_1.0	0.001 ± 0.000
37	AortProcOther_2.0	0.001 ± 0.000
38	LiverDis_0.0	0.001 ± 0.000
39	CPerfUtil_0.0	0.001 ± 0.000
40	CPerfUtil_1.0	0.001 ± 0.000
41	PostOpPneumo_1.0	0.001 ± 0.000
42	IntraClotFact_1	0.001 ± 0.000
43	COpPlndDelay_0.0	0.001 ± 0.000
44	ADLesTDis_1.0	0.001 ± 0.000
45	CRenFail_0.0	0.001 ± 0.000
46	HmO2_2	0.001 ± 0.000
47	AortProcTEVAR_0	0.001 ± 0.000
48	ArrPPaced_1.0	0.001 ± 0.000
49	AortProc_2	0.000 ± 0.000
50	VSTV_4,5,3	0.000 ± 0.000
51	VDInsufP_4,3	0.000 ± 0.000
52	TobaccoUse_4,6	0.000 ± 0.000
53	EndTy_0.0	0.000 ± 0.000
54	MedCChanTher_3,4	0.000 ± 0.000
55	MedADP5Days_4,3	0.000 ± 0.000
56	AortProc_4,5	0.000 ± 0.000

AUC, Area under the receiver operating characteristic curve; *SD*, standard deviation.

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TABLE E5. Decrease in predictive performance of the deep learning model with variable permutation for VTE

Rank	Permuted variable	Decrease in performance, AUC, mean ± SD
1	PLOS	0.143 ± 0.004
2	CRhythmDis_2	0.030 ± 0.004
3	CNComaEnceph_2	0.027 ± 0.003
4	CRhythmDis_4	0.025 ± 0.003
5	CNComaEnceph_1	0.015 ± 0.003
6	logVentHRS	0.010 ± 0.002
7	PASYS	0.008 ± 0.002
8	LOS	0.008 ± 0.001
9	SIDuration	0.007 ± 0.003
10	POpEF	0.007 ± 0.002
11	AdmitSrc_1.0	0.006 ± 0.002
12	LVEDD	0.006 ± 0.003
13	Hct	0.006 ± 0.002
14	ArrThird_0.0	0.005 ± 0.001
15	POpTTEch_0.0	0.005 ± 0.002
16	POpImagStdy_1	0.005 ± 0.002
17	COtAFib_1.0	0.005 ± 0.002
18	logICUHRS	0.005 ± 0.002
19	COtAFib_0.0	0.005 ± 0.002
20	WBC	0.004 ± 0.002
21	COtCoag_0.0	0.004 ± 0.001
22	POpImagStdy_4	0.004 ± 0.001
23	BdFFPU	0.004 ± 0.001
24	SlpApn_0.0	0.004 ± 0.001
25	COtCoag_1.0	0.004 ± 0.001
26	CPPneum_0.0	0.003 ± 0.001
27	IABP_1.0	0.003 ± 0.001
28	CHF_0.0	0.003 ± 0.001
29	ArrAFlutter_0.0	0.003 ± 0.002
30	VDTr_1.0	0.003 ± 0.001
31	CarCathPer_1.0	0.003 ± 0.001
32	VSAVPr_1.0	0.003 ± 0.001
33	CRhythmDis_5,3,1	0.003 ± 0.001
34	VDStenA_0.0	0.003 ± 0.001
35	CNComaEnceph_5	0.003 ± 0.000
36	BDTx_0.0	0.003 ± 0.001
37	CplegiaDeliv_1.0	0.003 ± 0.001
38	VDPulm_1.0	0.003 ± 0.001
39	AdmitSrc_3.0	0.003 ± 0.001
40	Arrhythmia_1.0	0.003 ± 0.001
41	Mcaid_0.0	0.003 ± 0.001
42	COtGI_1.0	0.003 ± 0.001
43	IABP_0.0	0.002 ± 0.001
44	IMedTran_0.0	0.002 ± 0.001
45	IABPWhen_1.0	0.002 ± 0.001
46	Region_PLAINS	0.002 ± 0.001
47	COtGI_0.0	0.002 ± 0.001
48	AortProcOther_2.0	0.002 ± 0.001
49	ThAoDisease_1.0	0.002 ± 0.001
50	AortaDisease_0.0	0.002 ± 0.001
51	BDTx_1.0	0.002 ± 0.001
52	PCAB_0.0	0.002 ± 0.001
53	AortProcDesProx_1,2	0.002 ± 0.001
54	CPerfUtil_1.0	0.002 ± 0.000
55	MedCoum_0.0	0.002 ± 0.000
56	AortProcDesProx_0	0.002 ± 0.001
57	InfEndo_0.0	0.002 ± 0.001
58	CPerfUtil_0.0	0.001 ± 0.000
59	VSAVPr_3.0	0.001 ± 0.000
60	ADLesTDis_1.0	0.001 ± 0.000
61	State_1.0	0.001 ± 0.000
62	COtMSF_1.0	0.001 ± 0.000
63	CNComaEnceph_6,3,4,7,8	0.001 ± 0.000
64	CanArtStAx_1.0	0.001 ± 0.000
65	AbxTiming_3.0	0.001 ± 0.000
66	Dialysis_1.0	0.001 ± 0.000
67	Pneumonia_4.0	0.001 ± 0.000
68	POpEKG_3	0.001 ± 0.000
69	CUltraFil_1.0	0.001 ± 0.000
70	CUltraFil_0.0	0.001 ± 0.000
71	AortProcTotArch_1.0	0.001 ± 0.000
72	COpReOth_0.0	0.001 ± 0.000

(Continued)

TABLE E5. Continued

AUC, Area under the receiver operating characteristic curve; *SD*, standard deviation.

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TABLE E6. Decrease in predictive performance of the deep learning model with variable permutation for stroke

Rank	Permuted variable	Decrease in performance, AUC, mean ± SD
1	PLOS	0.064 ± 0.003
2	CRhythmDis_2	0.056 ± 0.004
3	CRhythmDis_4	0.051 ± 0.004
4	logVentHRS	0.027 ± 0.002
5	COtAFib_1.0	0.016 ± 0.002
6	logICUHRS	0.015 ± 0.002
7	COtAFib_0.0	0.009 ± 0.002
8	CNComaEnceph_6,3,4,7,8	0.008 ± 0.001
9	CNComaEnceph_2	0.008 ± 0.002
10	POpEF	0.007 ± 0.002
11	TotCircArrTm	0.007 ± 0.001
12	VSMiImSz	0.005 ± 0.001
13	Age	0.005 ± 0.002
14	PerfusTm	0.004 ± 0.002
15	Mt30Stat_0.0	0.004 ± 0.001
16	IBdFFPU	0.003 ± 0.001
17	VSAoIm	0.003 ± 0.002
18	PASYSMeas_0.0	0.003 ± 0.001
19	CPlEff_1.0	0.003 ± 0.001
20	BdPlatU	0.003 ± 0.001
21	Mortalty_0.0	0.003 ± 0.001
22	MtDCStat_1.0	0.003 ± 0.000
23	VSAV_0	0.002 ± 0.001
24	MtDCStat_0.0	0.002 ± 0.000
25	CanVenStRtA_0.0	0.002 ± 0.001
26	MitralImplant_0.0	0.002 ± 0.001
27	COpReNon_0.0	0.002 ± 0.000
28	VSTV_2	0.002 ± 0.001
29	TobaccoUse_5	0.002 ± 0.001
30	VSTrIm	0.002 ± 0.001
31	VSAVPr_0.0	0.002 ± 0.001
32	ABG_1.0	0.002 ± 0.001
33	COpReBld_1	0.002 ± 0.001
34	CanVenStBi_1.0	0.002 ± 0.001
35	Mcaid_0.0	0.002 ± 0.001
36	ADLocRoot_1.0	0.002 ± 0.000
37	ReIntub_0.0	0.002 ± 0.001
38	POpEnzDrawn_0.0	0.002 ± 0.001
39	COpReBld_0	0.001 ± 0.001
40	COpReNon_1.0	0.001 ± 0.000
41	Cancer_0.0	0.001 ± 0.001
42	CSepsis_1.0	0.001 ± 0.000
43	AortProcTotArch_0.0	0.001 ± 0.000
44	ADLocAsc_1.0	0.001 ± 0.001
45	ADLocAsc_0.0	0.001 ± 0.000
46	AortProcDesProx_1,2	0.001 ± 0.000
47	CircArr_0.0	0.001 ± 0.000
48	MedInotr_0.0	0.001 ± 0.000
49	VSAVPr_777.0	0.001 ± 0.000
50	CNComaEnceph_5	0.001 ± 0.000
51	MediastRad_1.0	0.001 ± 0.000
52	CanArtStAx_1.0	0.001 ± 0.000
53	AnlrEnl_0.0	0.001 ± 0.000
54	MedADP5Days_4,3	0.000 ± 0.000
55	CVaLbIsc_0.0	0.000 ± 0.000
56	Mt30StatMeth_5.0	0.000 ± 0.000
57	MedCChanTher_3,4	0.000 ± 0.000
58	AortProc_4,5	0.000 ± 0.000

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TABLE E6. Continued

AUC, Area under the receiver operating characteristic curve; *SD*, standard deviation.

TABLE E7. Results of misclassification analysis for hemorrhage requiring reoperation

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	**Variable**	**Quadratic-chi distance ($P < .05$)**	**Rank**	**Variable**	**Quadratic-chi distance ($P < .05$)**
1	VentHrsTot	0.55	1	BdFFPU	0.35
2	BdPlatU	0.54	2	BdPlatU	0.34
3	BdFFPU	0.47	3	AortProcCoil	0.33
4	ECMO	0.43	4	BdCryoU	0.31
5	ICUInHrs	0.42	5	BdRBCU	0.29
6	BdCryoU	0.41	6	ECMO	0.25
7	PLOS	0.36	7	CRhythmDis	0.24
8	LOS	0.33	8	BldProd	0.21
9	ORDuration	0.33	9	COpPlndDelay	0.19
10	BdRBCU	0.33	10	VADImp	0.17
11	COpPlndDelay	0.33	11	COpReOth	0.16
12	COpReOth	0.32	12	COtMSF	0.15
13	COtMSF	0.31	13	VADProc	0.15
14	CUltraFil	0.30	14	AortProcTEVAR	0.15
15	COtCoag	0.29	15	ReIntub	0.14
16	COtArrst	0.29	16	VentHrsTot	0.13
17	MtDCStat	0.29	17	COtCoag	0.13
18	CNStrokP	0.29	18	CUltraFil	0.13
19	CVaLbIsc	0.28	19	VSAVPr	0.12
20	ReIntub	0.28	20	IBdFFPU	0.11
21	CSepsis	0.28	21	IBdRBCU	0.11
22	COpReNon	0.28	22	HmO2	0.11
23	CRenFail	0.28	23	AortProcThora	0.10
24	VADImp	0.28	24	VentHrsA	0.10
25	Mortalty	0.27	25	MtDCStat	0.09
26	VADProc	0.26	26	ICUInHrs	0.09
27	COtGI	0.25	27	MediastRad	0.09
28	IBdRBCU	0.25	28	Mortalty	0.09
29	IBdFFPU	0.24	29	CRenFail	0.09
30	CPPneum	0.24	30	MedOthAntiang	0.08
31	CVTE	0.24	31	IBdPlatU	0.08
32	IntraClotFact	0.24	32	IntraClotFact	0.08
33	Mt30Stat	0.24	33	MedInotr	0.08
34	CPlEff	0.22	34	CircArr	0.07
35	MedInotr	0.22	35	AortProcOther	0.07
36	IBdCryoU	0.20	36	CarCathPer	0.07
37	IBdPlatU	0.20	37	CombCardPCI	0.07
38	CanArtStAx	0.18	38	AortProcDesDist	0.07
39	IABP	0.17	39	MedNitIV	0.07
40	POpImagStdy	0.17	40	MedAplt5Days	0.06
41	MedCoum	0.16	41	Mt30Stat	0.06
42	CircArr	0.16	42	AortOccl	0.06

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TABLE E7. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance (*P* < .05)	Rank	Variable	Quadratic-chi distance (*P* < .05)
43	CarCathPer	0.16	43	CanArtStAx	0.06
44	PostOpPneumo	0.15	44	IBdCryoU	0.06
45	SurSInf	0.15	45	BDTx	0.06
46	AortProc	0.14	46	CVaLbIsc	0.06
47	ExtubOR	0.14	47	COpReNon	0.06
48	AortOccl	0.13	48	ADLocAsc	0.06
49	VSAVPr	0.13	49	ArrhythVV	0.06
50	OpONCard	0.13	50	ArrhythThird	0.06
51	AbxTiming	0.13	51	ApproachCon	0.05
52	InfEndo	0.12	52	ThAoDisease	0.05
53	Dialysis	0.11	53	Depression	0.05
54	ADLesTDis	0.10	54	COtArrst	0.05
55	CanArtStAort	0.10	55	CanArtStFem	0.05
56	AortProcThora	0.10	56	AortProc	0.05
57	AortProcDesMid	0.10	57	CSepsis	0.05
58	AortaDisease	0.10	58	Cancer	0.05
59	AortProcTEVAR	0.10	59	CPlEff	0.05
60	AortProcDesDist	0.10	60	MedSter	0.05
61	ThAoDisease	0.10	61	AortaDisease	0.04
62	MedSter	0.10	62	SlpApn	0.04
63	LiverDis	0.10	63	ChrLungD	0.04
64	PostCreat	0.09	64	AorticImplant	0.04
65	VSTV	0.09	65	PVD	0.04
66	AorticImplant	0.09	66	MedCChanTher	0.04
67	ADLocThora	0.09	67	ADLocThora	0.04
68	ArrhythVV	0.09	68	CanArtStAort	0.04
69	IABPWhen	0.09	69	CNStrokP	0.04
70	MtOpD	0.09	70	ArrhythSSS	0.04
71	PrCAB	0.09	71	AortProcTotArch	0.04
72	PrValve	0.09	72	ImmSupp	0.04
73	HDEFD	0.09	73	AoHemoDatAvail	0.04
74	CanArtStFem	0.08	74	CVD	0.04
75	HmO2	0.08	75	PostOpPneumo	0.04
76	AortProcDesProx	0.08	76	POCPCISt	0.03
77	POCPCIWhen	0.07	77	TricuspidImplant	0.03
78	VSMitRLeafRes	0.07	78	ORDuration	0.03
79	CanVenStBi	0.07	79	HITAnti	0.03
80	MedAmiodarone	0.07	80	Pneumonia	0.03
81	PriorHF	0.07	81	PLOS	0.03
82	Arrhythmia	0.07	82	ADLocArch	0.03
83	CanVenStFem	0.07	83	LOS	0.03
84	AortProcTotArch	0.07	84	CanVenStFem	0.03

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TABLE E7. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
85	RaceBlack	0.07	85	OPApp	0.03
86	CanVenStRtA	0.06	86	RaceOther	0.03
87	VDPulm	0.06	87	VDPulm	0.03
88	ImmSupp	0.06	88	PCO2	0.03
89	PayorGovMil	0.06	89	VSMiIm	0.03
90	COtAFib	0.06	90	VSMitRAnnulo	0.03
91	ADLocArch	0.06	91	AortProcDesMid	0.03
92	SIDuration	0.06	92	COtGI	0.03
93	OpOCard	0.06	93	ADLesTDis	0.03
94	ADLocDesThor	0.05	94	ADLocRoot	0.03
95	POpEnzDrawn	0.05	95	ADLesTAneur	0.03
96	InfEndTy	0.05	96	VSMitRPTFE	0.03
97	VDTr	0.05	97	IBldProd	0.03
98	CreatLst	0.05	98	AFibProc	0.03
99	PerfusTm	0.05	99	PayorGovMil	0.02
100	Mt30StatMeth	0.05	100	Dialysis	0.02
101	AortProcCoil	0.05	101	TotCircArrTm	0.02
102	VSMitRAnnulo	0.05	102	ABG	0.02
103	Dyslip	0.04	103	VDInsufA	0.02
104	RaceCaucasian	0.04	104	Mt30StatMeth	0.02
105	Pneumonia	0.04	105	AortProcAsc	0.02
106	VDInsufA	0.04	106	Diabetes	0.02
107	ABG	0.04	107	RaceCaucasian	0.02
108	ADLesTAneur	0.04	108	Gender	0.02
109	AortProcHemi	0.04	109	MedLipid	0.02
110	ArrhythPPaced	0.04	110	LiverDis	0.02
111	MedOthAntiang	0.04	111	MedLongActNit	0.02
112	CHF	0.04	112	PrevMI	0.02
113	MedNitIV	0.04	113	PO2	0.02
114	Syncope	0.04	114	IABPWhen	0.02
115	IVDrugAb	0.04	115	CVDTIA	0.02
116	CplegiaDeliv	0.04	116	PayorGovState	0.02
117	MediastRad	0.04	117	IVDrugAb	0.02
118	VSMitRPTFE	0.04	118	HDEFD	0.02
119	AdmitSrc	0.04	119	CPerfUtil	0.02
120	PayorGov	0.04	120	PayorNS	0.02
121	WBC	0.04	121	POCPCI	0.02
122	OpCAB	0.04	122	Dyslip	0.02
123	ADLocAsc	0.03	123	CreatLst	0.02
124	VSMiImSz	0.03	124	PostCreat	0.02
125	POCPCI	0.03	125	SIDuration	0.02
126	CombCardPCI	0.03	126	RaceAsian	0.02

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TABLE E7. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
127	LwstTemp	0.03	127	MedASA	0.02
128	ApproachCon	0.03	128	PerfusTm	0.02
129	PrCVInt	0.03	129	IABP	0.02
130	ArrhythSecond	0.03	130	CPPneum	0.02
131	POpEKG	0.03	131	VDTr	0.01
132	TotCircArrTm	0.03	132	CPT1Code1	0.01
133	MedLongActNit	0.03	133	IMedEACA	0.01
134	VDAort	0.03	134	MedADP5Days	0.01
135	ChrLungD	0.03	135	COtAFib	0.01
136	DLCO	0.03	136	ArrhythSecond	0.01
137	MedLipid	0.03	137	LVSD	0.01
138	VDInsufT	0.03	138	VSTrImSz	0.01
139	HITAnti	0.03	139	VDStenA	0.01
140	HighIntraGlu	0.02	140	POpEF	0.01
141	MedADP5Days	0.02	141	OpCAB	0.01
142	LVSD	0.02	142	SurSInf	0.01
143	PayorGovMcare	0.02	143	SynthGft	0.01
144	VentHrsA	0.02	144	MedAmiodarone	0.01
145	ArrhythThird	0.02	145	DHCATm	0.01
146	PVD	0.02	146	HighIntraGlu	0.01
147	ADLocRoot	0.02	147	POpImagStdy	0.01
148	SynthGft	0.02	148	AnlrEnl	0.01
149	PCO2	0.02	149	TobaccoUse	0.01
150	PASYS	0.02	150	RaceBlack	0.01
151	MitralImplant	0.02	151	CplegiaDeliv	0.01
152	Hct	0.02	152	VSMV	0.01
153	RFHemoglobin	0.02	153	POpTTECh	0.01
154	HDEF	0.02	154	OpONCard	0.01
155	Alcohol	0.02	155	LwstTemp	0.01
156	MedASA	0.02	156	LVEDD	0.01
157	VSAoIm	0.02	157	MedACoag	0.01
158	MedCChanTher	0.02	158	PayorHMO	0.01
159	AortProcAsc	0.02	159	WeightKg	0.01
160	LVEDD	0.02	160	VSAV	0.01
161	PayorNS	0.02	161	PayorGovMcaid	0.01
162	OPApp	0.02	162	VSTV	0.01
163	MedACEI48	0.02	163	Syncope	0.01
164	VSTrIm	0.02	164	MedCoum	0.01
165	VSMiIm	0.02	165	VDAort	0.01
166	VDMit	0.02	166	AortProcRoot	0.01
167	VDInsufP	0.02	167	VDInsufP	0.01
168	CPT1Code3	0.02	168	PrCAB	0.01

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TABLE E7. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
169	RaceAsian	0.02	169	PayorCom	0.01
170	AortProcRoot	0.02	170	POCPCIWhen	0.01
171	DHCATm	0.02	171	RFHemoglobin	0.01
172	BDTx	0.02	172	VDInsufT	0.01
173	Diabetes	0.02	173	CanVenStBi	0.01
174	VDStenA	0.01	174	BSA	0.01
175	POpEF	0.01	175	CNComaEnceph	0.01
176	AoHemoDatAvail	0.01	176	POpEnzDrawn	0.01
177	CVDPCarSurg	0.01	177	POpEFD	0.01
178	IMedTran	0.01	178	POpEKG	0.01
179	PO2	0.01	179	VSAoImSz	0.01
180	CPT1Code2	0.01	180	PayorGovMcare	0.01
181	VSMV	0.01	181	ADLocDesThor	0.01
182	PFT	0.01	182	ArrhythAFlutter	0.01
183	PrevMI	0.01	183	MedBetaTher	0.01
184	PayorGovState	0.01	184	VSMiImSz	0.01
185	CVA	0.01	185	Platelets	0.01
186	CPerfUtil	0.01	186	MtOpD	0.01
187	MedACoag	0.01	187	WBC	0.01
188	IMedEACA	0.01	188	Age	0.01
189	SlpApn	0.01	189	VSAoIm	0.01
190	AortProcOther	0.01	190	CHF	0.01
191	TobaccoUse	0.01	191	PayorGov	0.01
192	VDInsufM	0.01	192	DimAvail	0.01
193	Platelets	0.01	193	PrValve	0.01
194	AnlrEnl	0.01	194	Hypertn	0.01
195	VSTrImSz	0.01	195	Hct	0.01
196	CVDTIA	0.01	196	PriorHF	0.01
197	CPT1Code1	0.01	197	AdmitSrc	0.01
198	AFibProc	0.01	198	CerOxUsed	0.01
199	Ethnicity	0.01	199	AddIntraopPAnti	0.01
200	CerOxUsed	0.01	200	VSMVPr	0.01
201	MedAplt5Days	0.01	201	HDEF	0.01
202	ArrhythAFlutter	0.01	202	OpValve	0.01
203	VSAoImSz	0.01	203	AbxTiming	0.00
204	ArrhythSSS	0.01	204	InfEndo	0.00
205	Cancer	0.01	205	PFT	0.00
206	TricuspidImplant	0.01	206	OCarASDPFO	0.00
207	PayorCom	0.01	207	ExtubOR	0.00
208	OCarASDPFO	0.01	208	ArrhythPPaced	0.00
209	VSAV	0.01	209	DLCO	0.00
210	PASYSMeas	0.01	210	Alcohol	0.00

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TABLE E7. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
211	CVD	0.01	211	CVA	0.00
212	MedBetaTher	0.00	212	HeightCm	0.00
213	AddIntraopPAnti	0.00	213	PASYS	0.00
214	PayorHMO	0.00	214	MedACEI48	0.00
215	Age	0.00	215	MitralImplant	0.00
216	Depression	0.00	216	LwstTempSrc	0.00
217	SurgYear	0.00	217	InfEndTy	0.00
218	DimAvail	0.00	218	CVTE	0.00
219	HeightCm	0.00	219	CVDPCarSurg	0.00
220	LwstTempSrc	0.00	220	Ethnicity	0.00
221	Gender	0.00	221	CanVenStRtA	0.00
222	Hypertn	0.00	222	IMedTran	0.00
223	SiteID	0.00	223	VDMit	0.00
224	HospID	0.00	224	AortProcHemi	0.00
225	BSA	0.00	225	Region	0.00
226	RaceOther	0.00	226	OpOCard	0.00
227	POCPCISt	0.00	227	PrCVInt	0.00
228	PayorGovMcaid	0.00	228	VDInsufM	0.00
			229	SurgYear	0.00
			230	Arrhythmia	0.00
			231	VSMitRLeafRes	0.00
			232	AortProcDesProx	0.00

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TABLE E8. Results of misclassification analysis for venous thromboembolism

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
1	VentHrsTot	0.66	1	AortProcTEVAR	0.34
2	ICUInHrs	0.51	2	VentHrsA	0.32
3	VentHrsA	0.50	3	VentHrsTot	0.32
4	CNStrokP	0.44	4	ICUInHrs	0.31
5	PLOS	0.44	5	COtCoag	0.30
6	ECMO	0.36	6	AortProcCoil	0.26
7	LOS	0.33	7	CVaLbIsc	0.25
8	ORDuration	0.33	8	COpReNon	0.25
9	COtCoag	0.33	9	ArrhythSecond	0.23
10	CVaLbIsc	0.33	10	CSepsis	0.23
11	CSepsis	0.33	11	BdFFPU	0.23
12	COpReNon	0.32	12	CircArr	0.21
13	CPPneum	0.31	13	VSAVPr	0.21
14	BdPlatU	0.31	14	AorticImplant	0.20
15	BdRBCU	0.31	15	CPPneum	0.19
16	CUltraFil	0.31	16	CanArtStAx	0.19
17	COtGI	0.31	17	IntraClotFact	0.19
18	COpPlndDelay	0.30	18	BdRBCU	0.18
19	COtMSF	0.29	19	ADLocDesThor	0.18
20	COpReOth	0.29	20	IBdFFPU	0.17
21	ReIntub	0.29	21	MedCoum	0.17
22	CRenFail	0.29	22	ReIntub	0.17
23	COtArrst	0.27	23	COpPlndDelay	0.17
24	CPlEff	0.26	24	BdPlatU	0.17
25	BdFFPU	0.25	25	COtGI	0.17
26	MedInotr	0.25	26	ExtubOR	0.16
27	VADProc	0.25	27	CarCathPer	0.15
28	VADImp	0.25	28	IBdPlatU	0.15
29	ExtubOR	0.25	29	ECMO	0.15
30	POpImagStdy	0.23	30	POpImagStdy	0.15
31	Mortalty	0.23	31	AortProcHemi	0.15
32	MtDCStat	0.23	32	AortProc	0.15
33	IntraClotFact	0.23	33	CUltraFil	0.15
34	VSAVPr	0.23	34	AortProcThora	0.14
35	MedCoum	0.22	35	DHCATm	0.14
36	SurSInf	0.21	36	CRhythmDis	0.14
37	IBdRBCU	0.21	37	COpReOth	0.14
38	COpReBld	0.21	38	ADLocThora	0.14
39	AbxTiming	0.20	39	AbxTiming	0.14
40	IBdFFPU	0.20	40	AortProcDesMid	0.14
41	CanArtStAx	0.20	41	MedAplt5Days	0.14
42	CarCathPer	0.19	42	IBdRBCU	0.14

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TABLE E8. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
43	OpONCard	0.19	43	IBdCryoU	0.14
44	AortProcDesDist	0.19	44	COtMSF	0.13
45	CircArr	0.19	45	CRenFail	0.13
46	AortProcThora	0.18	46	VADProc	0.13
47	PostOpPneumo	0.18	47	MedInotr	0.13
48	IBdCryoU	0.18	48	CanArtStAort	0.13
49	AorticImplant	0.18	49	CPlEff	0.13
50	IABP	0.18	50	AortProcTotArch	0.13
51	AortProcDesMid	0.17	51	CNStrokP	0.13
52	IBdPlatU	0.17	52	ArrhythSSS	0.13
53	AortProcTotArch	0.17	53	BdCryoU	0.12
54	InfEndo	0.16	54	MediastRad	0.12
55	Mt30Stat	0.16	55	ThAoDisease	0.12
56	AortProcDesProx	0.16	56	POpEnzDrawn	0.12
57	ADLocThora	0.15	57	ArrhythVV	0.12
58	AortProcTEVAR	0.15	58	InfEndTy	0.12
59	VSMitRPTFE	0.14	59	VSMitRPTFE	0.12
60	AortProc	0.13	60	CNComaEnceph	0.11
61	ArrhythVV	0.13	61	InfEndo	0.11
62	Dialysis	0.13	62	AortaDisease	0.11
63	AortOccl	0.13	63	AortProcDesDist	0.11
64	VSMitRLeafRes	0.13	64	PayorNS	0.11
65	RaceBlack	0.12	65	POCPCIWhen	0.11
66	VSTV	0.12	66	MitralImplant	0.11
67	BdCryoU	0.12	67	CanArtStFem	0.11
68	POCPCIWhen	0.12	68	Mt30StatMeth	0.10
69	POpEnzDrawn	0.12	69	SurSInf	0.10
70	HmO2	0.11	70	PostCreat	0.10
71	ThAoDisease	0.11	71	OpONCard	0.10
72	CombCardPCI	0.11	72	IVDrugAb	0.10
73	CanArtStAort	0.11	73	MedOthAntiang	0.10
74	MedSter	0.11	74	RaceAsian	0.10
75	ADLocDesThor	0.11	75	ApproachCon	0.09
76	MedAmiodarone	0.10	76	VADImp	0.09
77	OPApp	0.10	77	ArrhythThird	0.09
78	InfEndTy	0.10	78	RaceBlack	0.09
79	AortaDisease	0.10	79	HDEFD	0.09
80	Mt30StatMeth	0.09	80	HITAnti	0.08
81	CanVenStBi	0.09	81	VSMitRLeafRes	0.08
82	Pneumonia	0.08	82	VSTV	0.08
83	Arrhythmia	0.08	83	Dialysis	0.07
84	LiverDis	0.08	84	ImmSupp	0.07

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TABLE E8. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
85	OpOCard	0.08	85	CVDPCarSurg	0.07
86	PostCreat	0.08	86	CombCardPCI	0.07
87	HDEFD	0.08	87	AortOccl	0.07
88	TricuspidImplant	0.08	88	SynthGft	0.07
89	CanArtStFem	0.08	89	ArrhythAFlutter	0.07
90	VDTr	0.07	90	Ethnicity	0.06
91	MtOpD	0.07	91	MedAmiodarone	0.06
92	CanVenStRtA	0.07	92	RaceCaucasian	0.06
93	ArrhythThird	0.07	93	Cancer	0.06
94	ImmSupp	0.07	94	ADLesTAneur	0.06
95	RaceCaucasian	0.07	95	CplegiaDeliv	0.06
96	ArrhythPPaced	0.07	96	BldProd	0.06
97	MedAplt5Days	0.07	97	VSMitRAnnulo	0.05
98	PayorGovMil	0.07	98	MedADP5Days	0.05
99	PriorHF	0.07	99	Mortalty	0.05
100	COtAFib	0.06	100	MtOpD	0.05
101	ADLocArch	0.06	101	OpOCard	0.05
102	ApproachCon	0.06	102	COtArrst	0.05
103	AortProcHemi	0.06	103	BDTx	0.05
104	VSMitRAnnulo	0.06	104	CanVenStBi	0.05
105	AdmitSrc	0.06	105	CanVenStFem	0.04
106	VDPulm	0.06	106	AnlrEnl	0.04
107	ChrLungD	0.06	107	Arrhythmia	0.04
108	IABPWhen	0.06	108	AortProcAsc	0.04
109	ArrhythSecond	0.06	109	COpReBld	0.04
110	IVDrugAb	0.06	110	AoHemoDatAvail	0.04
111	RaceAsian	0.06	111	MedNitIV	0.04
112	CanVenStFem	0.06	112	AdmitSrc	0.04
113	MedOthAntiang	0.06	113	OPApp	0.04
114	WBC	0.05	114	VSTrIm	0.04
115	AortProcCoil	0.05	115	LwstTemp	0.04
116	SynthGft	0.05	116	OCarASDPFO	0.04
117	PrValve	0.05	117	PayorGov	0.04
118	IMedTran	0.05	118	IMedTran	0.04
119	ADLesTAneur	0.05	119	CVDTIA	0.04
120	CVDPCarSurg	0.05	120	LwstTempSrc	0.04
121	POCPCISt	0.05	121	IABP	0.04
122	PayorNS	0.05	122	ADLocRoot	0.04
123	Alcohol	0.05	123	CanVenStRtA	0.03
124	CplegiaDeliv	0.05	124	PerfusTm	0.03
125	MedNitIV	0.05	125	ADLocArch	0.03
126	PVD	0.04	126	ADLocAsc	0.03

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TABLE E8. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
127	PerfusTm	0.04	127	PostOpPneumo	0.03
128	SIDuration	0.04	128	POCPCISt	0.03
129	HITAnti	0.04	129	VDTr	0.03
130	PrCAB	0.04	130	PCO2	0.03
131	MediastRad	0.04	131	CreatLst	0.03
132	VSMiImSz	0.04	132	MedACoag	0.03
133	MedACoag	0.04	133	HmO2	0.03
134	CreatLst	0.04	134	LVSD	0.03
135	OpCAB	0.04	135	MtDCStat	0.03
136	ABG	0.04	136	PrValve	0.03
137	AortProcOther	0.04	137	RaceOther	0.03
138	PrCVInt	0.04	138	SIDuration	0.03
139	VSAV	0.03	139	PrCVInt	0.03
140	MedLipid	0.03	140	Alcohol	0.03
141	LwstTemp	0.03	141	PayorGovState	0.03
142	VSTrIm	0.03	142	IMedEACA	0.03
143	CHF	0.03	143	MedCChanTher	0.02
144	DLCO	0.03	144	ORDuration	0.02
145	BDTx	0.03	145	MedLipid	0.02
146	HDEF	0.03	146	AortProcDesProx	0.02
147	PayorGov	0.03	147	LiverDis	0.02
148	Dyslip	0.03	148	VSAoIm	0.02
149	MedLongActNit	0.03	149	CVD	0.02
150	CPerfUtil	0.03	150	MedSter	0.02
151	LVSD	0.03	151	LVEDD	0.02
152	IMedEACA	0.03	152	WBC	0.02
153	MedASA	0.03	153	MedACEI48	0.02
154	PCO2	0.03	154	Dyslip	0.02
155	PO2	0.03	155	VDAort	0.02
156	OCarASDPFO	0.03	156	PFT	0.02
157	Hct	0.02	157	VSMV	0.02
158	POCPCI	0.02	158	MedASA	0.02
159	Syncope	0.02	159	POpEKG	0.02
160	DimAvail	0.02	160	AortProcRoot	0.02
161	CVDTIA	0.02	161	DimAvail	0.02
162	VDInsufP	0.02	162	IBldProd	0.02
163	CVD	0.02	163	CPerfUtil	0.02
164	VSMV	0.02	164	Region	0.01
165	LwstTempSrc	0.02	165	DLCO	0.01
166	Gender	0.02	166	Diabetes	0.01
167	MedACEI48	0.02	167	Syncope	0.01
168	HighIntraGlu	0.02	168	SlpApn	0.01

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TABLE E8. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
169	PASYS	0.02	169	VSMiIm	0.01
170	MitralImplant	0.02	170	ChrLungD	0.01
171	Region	0.02	171	ABG	0.01
172	VDInsufT	0.02	172	TobaccoUse	0.01
173	VDMit	0.02	173	VDInsufP	0.01
174	PayorGovMcare	0.02	174	MedLongActNit	0.01
175	ADLocAsc	0.02	175	PO2	0.01
176	SlpApn	0.02	176	Gender	0.01
177	RFHemoglobin	0.02	177	MedBetaTher	0.01
178	LVEDD	0.02	178	VSAV	0.01
179	AnlrEnl	0.02	179	TricuspidImplant	0.01
180	PrevMI	0.02	180	Age	0.01
181	Platelets	0.02	181	PriorHF	0.01
182	PFT	0.01	182	HDEF	0.01
183	VSMiIm	0.01	183	PayorGovMil	0.01
184	Hypertn	0.01	184	PayorGovMcaid	0.01
185	POpEF	0.01	185	PrevMI	0.01
186	AortProcAsc	0.01	186	VSAoImSz	0.01
187	POpEKG	0.01	187	POpEF	0.01
188	VDInsufA	0.01	188	PayorCom	0.01
189	AoHemoDatAvail	0.01	189	IABPWhen	0.01
190	VSAoIm	0.01	190	Hypertn	0.01
191	ADLocRoot	0.01	191	AddIntraopPAnti	0.01
192	PayorGovMcaid	0.01	192	Pneumonia	0.01
193	DHCATm	0.01	193	Mt30Stat	0.01
194	VDInsufM	0.01	194	PASYS	0.01
195	CPT1Code1	0.01	195	VSMiImSz	0.01
196	VSTrImSz	0.01	196	CPT1Code1	0.01
197	Cancer	0.01	197	WeightKg	0.01
198	AortProcRoot	0.01	198	RFHemoglobin	0.01
199	VSAoImSz	0.01	199	VSMVPr	0.01
200	CerOxUsed	0.01	200	PrCAB	0.01
201	Ethnicity	0.01	201	PVD	0.01
202	AddIntraopPAnti	0.01	202	SurgYear	0.01
203	WeightKg	0.01	203	Depression	0.01
204	TobaccoUse	0.01	204	VDInsufM	0.01
205	Age	0.01	205	AortProcOther	0.00
206	BSA	0.01	206	CHF	0.00
207	AFibProc	0.01	207	Hct	0.00
208	Depression	0.01	208	VDInsufT	0.00
209	HeightCm	0.01	209	HeightCm	0.00
210	PASYSMeas	0.00	210	VDMit	0.00

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TABLE E8. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
211	MedBetaTher	0.00	211	VDPulm	0.00
212	ArrhythAFlutter	0.00	212	PayorGovMcare	0.00
213	ArrhythSSS	0.00	213	BSA	0.00
214	HospID	0.00	214	CerOxUsed	0.00
215	SiteID	0.00	215	VDInsufA	0.00
216	PayorCom	0.00	216	PayorHMO	0.00
217	OpValve	0.00	217	Platelets	0.00
218	SurgYear	0.00	218	AFibProc	0.00
219	RaceOther	0.00	219	ArrhythPPaced	0.00
220	MedCChanTher	0.00			
221	PayorGovState	0.00			
222	PayorHMO	0.00			
223	MedADP5Days	0.00			
224	Diabetes	0.00			
225	VDAort	0.00			

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TABLE E9. Results of misclassification analysis for stroke

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance (*P* < .05)	Rank	Variable	Quadratic-chi distance (*P* < .05)
1	VentHrsTot	0.63	1	ORDuration	0.50
2	ICUInHrs	0.51	2	CRhythmDis	0.38
3	PLOS	0.40	3	AortProcCoil	0.33
4	ECMO	0.38	4	VentHrsTot	0.30
5	VentHrsA	0.37	5	CNComaEnceph	0.30
6	BdPlatU	0.35	6	ICUInHrs	0.27
7	LOS	0.33	7	MtDCStat	0.24
8	ORDuration	0.33	8	Mortalty	0.24
9	COpReNon	0.32	9	PLOS	0.23
10	COtMSF	0.32	10	AorticImplant	0.22
11	CSepsis	0.32	11	Mt30Stat	0.21
12	CVaLbIsc	0.31	12	COtMSF	0.20
13	CPPneum	0.30	13	CircArr	0.20
14	CVTE	0.30	14	VentHrsA	0.20
15	COtCoag	0.30	15	COpReNon	0.20
16	ReIntub	0.30	16	ECMO	0.20
17	MtDCStat	0.29	17	BdFFPU	0.19
18	CRenFail	0.29	18	HmO2	0.19
19	Mortalty	0.29	19	ExtubOR	0.19
20	CUltraFil	0.28	20	LOS	0.19
21	BdRBCU	0.28	21	ADLocThora	0.18
22	COpPlndDelay	0.28	22	CSepsis	0.18
23	COtGI	0.27	23	BdPlatU	0.17
24	COpReOth	0.27	24	AortProcTEVAR	0.17
25	COtArrst	0.26	25	VSAVPr	0.17
26	Mt30Stat	0.25	26	AortProc	0.16
27	BdFFPU	0.23	27	CVTE	0.16
28	ExtubOR	0.23	28	IntraClotFact	0.15
29	CircArr	0.20	29	ReIntub	0.15
30	VADImp	0.20	30	CanArtStAx	0.15
31	COpReBld	0.19	31	COpPlndDelay	0.15
32	CanArtStAx	0.18	32	CVaLbIsc	0.14
33	POpImagStdy	0.18	33	CPPneum	0.14
34	VADProc	0.18	34	AortProcOther	0.14
35	CPlEff	0.18	35	CanArtStFem	0.14
36	IBdRBCU	0.18	36	CanArtStAort	0.13
37	MedInotr	0.17	37	VADImp	0.13
38	IntraClotFact	0.17	38	COtCoag	0.13
39	IBdFFPU	0.17	39	AortaDisease	0.13
40	AorticImplant	0.15	40	ThAoDisease	0.13
41	OpONCard	0.15	41	ADLocDesThor	0.13
42	AortProc	0.15	42	PostOpPneumo	0.12

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TABLE E9. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
43	AortProcTEVAR	0.15	43	AortProcAsc	0.12
44	AortProcTotArch	0.15	44	IBdFFPU	0.12
45	AortProcDesDist	0.15	45	HDEFD	0.12
46	VSAVPr	0.15	46	CarCathPer	0.12
47	AortProcDesProx	0.14	47	DHCATm	0.12
48	ADLocThora	0.14	48	BdRBCU	0.11
49	IBdPlatU	0.14	49	SynthGft	0.11
50	AortProcDesMid	0.14	50	MedCoum	0.10
51	BdCryoU	0.14	51	TotCircArrTm	0.10
52	IABP	0.13	52	CanVenStFem	0.10
53	MedCoum	0.13	53	AortProcTotArch	0.09
54	IBdCryoU	0.12	54	CombCardPCI	0.09
55	CarCathPer	0.12	55	OpONCard	0.09
56	AortProcThora	0.11	56	ChrLungD	0.09
57	ADLocDesThor	0.11	57	AortProcThora	0.09
58	SurSInf	0.11	58	IBdCryoU	0.09
59	ThAoDisease	0.10	59	BdCryoU	0.09
60	CanArtStAort	0.10	60	BDTx	0.09
61	AortaDisease	0.10	61	CPlEff	0.08
62	HDEFD	0.10	62	IBdRBCU	0.08
63	PostOpPneumo	0.10	63	CUltraFil	0.08
64	AbxTiming	0.09	64	TricuspidImplant	0.08
65	CVD	0.09	65	VADProc	0.08
66	POpEnzDrawn	0.09	66	ArrhythSSS	0.08
67	PrCAB	0.09	67	AortProcHemi	0.08
68	PostCreat	0.09	68	COtGI	0.07
69	IABPWhen	0.08	69	VSMitRLeafRes	0.07
70	MitralImplant	0.08	70	CRenFail	0.07
71	CanArtStFem	0.08	71	IBdPlatU	0.07
72	AortProcHemi	0.08	72	PrCAB	0.07
73	OPApp	0.08	73	InfEndTy	0.07
74	PVD	0.07	74	AortProcDesProx	0.06
75	AortProcCoil	0.07	75	CVD	0.06
76	Dialysis	0.07	76	IMedTran	0.06
77	VSMitRPTFE	0.07	77	SlpApn	0.06
78	PayorGovMcare	0.07	78	IMedEACA	0.06
79	InfEndTy	0.07	79	MedSter	0.06
80	VSMitRLeafRes	0.07	80	VSTV	0.06
81	Hypertn	0.07	81	COpReOth	0.06
82	ADLocArch	0.07	82	MedOthAntiang	0.06
83	AortOccl	0.07	83	PostCreat	0.06
84	ADLocAsc	0.06	84	PayorGovMil	0.06

(Continued)

TABLE E9. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
85	AortProcAsc	0.06	85	AortProcDesDist	0.06
86	COtAFib	0.06	86	CPerfUtil	0.06
87	PayorGov	0.06	87	Depression	0.06
88	IVDrugAb	0.05	88	Cancer	0.05
89	Mt30StatMeth	0.05	89	PayorNS	0.05
90	ADLesTAneur	0.05	90	IABPWhen	0.05
91	MedOthAntiang	0.05	91	OpOCard	0.05
92	PayorGovMcaid	0.05	92	ABG	0.05
93	POCPCIWhen	0.05	93	Ethnicity	0.05
94	RaceBlack	0.05	94	SurSInf	0.05
95	DHCATm	0.05	95	PFT	0.05
96	Arrhythmia	0.05	96	AFibProc	0.05
97	PrValve	0.05	97	AortOccl	0.05
98	AortProcOther	0.05	98	CVDPCarSurg	0.05
99	SynthGft	0.04	99	POpEnzDrawn	0.05
100	PayorGovState	0.04	100	POpImagStdy	0.05
101	AdmitSrc	0.04	101	ADLocAsc	0.05
102	CreatLst	0.04	102	RaceAsian	0.04
103	Gender	0.04	103	Mt30StatMeth	0.04
104	CHF	0.04	104	MedAmiodarone	0.04
105	PerfusTm	0.04	105	Pneumonia	0.04
106	AnlrEnl	0.04	106	InfEndo	0.04
107	SIDuration	0.04	107	LwstTemp	0.04
108	CanVenStBi	0.04	108	OPApp	0.04
109	PriorHF	0.04	109	MtOpD	0.04
110	ABG	0.04	110	VSMitRPTFE	0.04
111	PayorGovMil	0.04	111	MedNitIV	0.04
112	MedNitIV	0.04	112	MediastRad	0.04
113	POCPCI	0.04	113	COtArrst	0.04
114	HmO2	0.04	114	PriorHF	0.04
115	CanVenStRtA	0.04	115	MedInotr	0.04
116	WBC	0.04	116	VSTrImSz	0.04
117	VDTr	0.03	117	PVD	0.04
118	ArrhythThird	0.03	118	RaceBlack	0.04
119	OCarASDPFO	0.03	119	WBC	0.03
120	PFT	0.03	120	PerfusTm	0.03
121	SlpApn	0.03	121	VSMiImSz	0.03
122	MtOpD	0.03	122	MedLongActNit	0.03
123	InfEndo	0.03	123	AortProcRoot	0.03
124	IMedTran	0.03	124	AoHemoDatAvail	0.03
125	RaceAsian	0.03	125	ADLesTAneur	0.03
126	VSTrIm	0.03	126	PrValve	0.03

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TABLE E9. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
127	LwstTemp	0.03	127	ApproachCon	0.03
128	Alcohol	0.03	128	LiverDis	0.03
129	ApproachCon	0.03	129	RaceCaucasian	0.03
130	CanVenStFem	0.03	130	Dyslip	0.03
131	ArrhythAFlutter	0.03	131	MedADP5Days	0.03
132	VDInsufA	0.03	132	BldProd	0.03
133	CplegiaDeliv	0.03	133	POpEKG	0.03
134	VSMiImSz	0.03	134	SIDuration	0.02
135	CombCardPCI	0.03	135	Hypertn	0.02
136	MedAplt5Days	0.02	136	HighIntraGlu	0.02
137	CVDPCarSurg	0.02	137	Gender	0.02
138	VDPulm	0.02	138	AdmitSrc	0.02
139	HighIntraGlu	0.02	139	CplegiaDeliv	0.02
140	OpCAB	0.02	140	VDStenA	0.02
141	IMedEACA	0.02	141	POCPCI	0.02
142	ArrhythVV	0.02	142	ImmSupp	0.02
143	VDMit	0.02	143	AortProcDesMid	0.02
144	DLCO	0.02	144	COpReBld	0.02
145	VDAort	0.02	145	ArrhythPPaced	0.02
146	ArrhythSecond	0.02	146	PO2	0.02
147	PayorHMO	0.02	147	Syncope	0.02
148	MedLongActNit	0.02	148	WeightKg	0.02
149	MedCChanTher	0.02	149	AnlrEnl	0.02
150	POpEKG	0.02	150	CanVenStRtA	0.02
151	RaceOther	0.02	151	MedAplt5Days	0.02
152	VSMV	0.02	152	VSAV	0.02
153	VSMiIm	0.02	153	MedLipid	0.02
154	RaceCaucasian	0.02	154	PayorGovMcaid	0.02
155	PO2	0.02	155	ArrhythSecond	0.02
156	MedLipid	0.02	156	PrCVInt	0.02
157	VDStenA	0.02	157	POCPCISt	0.02
158	PrevMI	0.02	158	PayorGov	0.02
159	HDEF	0.02	159	ArrhythAFlutter	0.01
160	BDTx	0.02	160	OpCAB	0.01
161	PCO2	0.02	161	MedCChanTher	0.01
162	ImmSupp	0.02	162	AbxTiming	0.01
163	ChrLungD	0.02	163	MedASA	0.01
164	Syncope	0.02	164	LwstTempSrc	0.01
165	ArrhythPPaced	0.02	165	VDInsufA	0.01
166	VSAoImSz	0.02	166	VSMiIm	0.01
167	PayorNS	0.01	167	VDPulm	0.01
168	OpValve	0.01	168	RFHemoglobin	0.01

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TABLE E9. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
169	MedACoag	0.01	169	Platelets	0.01
170	Diabetes	0.01	170	CHF	0.01
171	CPT1Code3	0.01	171	ArrhythVV	0.01
172	Cancer	0.01	172	CVDTIA	0.01
173	Pneumonia	0.01	173	POCPCIWhen	0.01
174	CerOxUsed	0.01	174	VSMitRAnnulo	0.01
175	LVSD	0.01	175	CerOxUsed	0.01
176	VDInsufT	0.01	176	IVDrugAb	0.01
177	VSTV	0.01	177	IBldProd	0.01
178	Hct	0.01	178	VSMV	0.01
179	HITAnti	0.01	179	HITAnti	0.01
180	TricuspidImplant	0.01	180	DLCO	0.01
181	VDInsufM	0.01	181	PayorHMO	0.01
182	AortProcRoot	0.01	182	MedACEI48	0.01
183	PASYS	0.01	183	BSA	0.01
184	ADLocRoot	0.01	184	MedBetaTher	0.01
185	VDInsufP	0.01	185	PayorGovMcare	0.01
186	MedAmiodarone	0.01	186	VDTr	0.01
187	VSMitRAnnulo	0.01	187	Arrhythmia	0.01
188	VSAV	0.01	188	VSTrIm	0.01
189	AFibProc	0.01	189	AddIntraopPAnti	0.01
190	LwstTempSrc	0.01	190	PASYSMeas	0.01
191	VSTrImSz	0.01	191	POpEFD	0.01
192	HeightCm	0.01	192	Alcohol	0.01
193	PayorCom	0.01	193	VDAort	0.01
194	OpOCard	0.01	194	VSMVPr	0.01
195	POpEF	0.01	195	RaceOther	0.01
196	CPT1Code2	0.01	196	ArrhythThird	0.01
197	MedASA	0.01	197	POpEF	0.01
198	ArrhythSSS	0.01	198	Dialysis	0.01
199	AddIntraopPAnti	0.01	199	DimAvail	0.01
200	PrCVInt	0.01	200	CreatLst	0.01
201	Platelets	0.01	201	Hct	0.01
202	CPerfUtil	0.01	202	HeightCm	0.01
203	TobaccoUse	0.01	203	VDMit	0.01
204	PASYSMeas	0.01	204	Diabetes	0.01
205	LiverDis	0.01	205	MitralImplant	0.01
206	MedBetaTher	0.01	206	VDInsufM	0.00
207	VSAoIm	0.01	207	ADLocRoot	0.00
208	DimAvail	0.01	208	POpTTECh	0.00
209	POCPCISt	0.00	209	VDInsufP	0.00
210	LVEDD	0.00	210	LVSD	0.00

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TABLE E9. Continued

Always correctly classified as not having complication vs always misclassified as having complication			Always correctly classified as having complication vs always misclassified as not having complication		
Rank	Variable	Quadratic-chi distance ($P < .05$)	Rank	Variable	Quadratic-chi distance ($P < .05$)
211	MedSter	0.00	211	OCarASDPFO	0.00
212	Depression	0.00	212	Age	0.00
213	Ethnicity	0.00	213	IABP	0.00
214	MedACEI48	0.00	214	SurgYear	0.00
215	CPT1Code1	0.00	215	CanVenStBi	0.00
216	CVDTIA	0.00	216	PayorCom	0.00
217	Dyslip	0.00	217	OpValve	0.00
218	MediastRad	0.00	218	Region	0.00
219	WeightKg	0.00	219	VDInsufT	0.00
220	Region	0.00	220	PayorGovState	0.00
221	MedADP5Days	0.00	221	PASYS	0.00
222	AoHemoDatAvail	0.00	222	VSAoImSz	0.00
223	SurgYear	0.00	223	LVEDD	0.00
			224	HDEF	0.00
			225	VSAoIm	0.00
			226	PrevMI	0.00
			227	MedACoag	0.00

TABLE E10. Performance of the deep learning feedforward neural network applied to a balanced testing cohort

Postoperative complication	Accuracy	Sensitivity	Specificity	PPV	NPV	F_1 score	Discrimination AUC (95% CI)	Calibration
Hemorrhage requiring reoperation	0.94	0.95	0.93	0.93	0.95	0.94	0.98 (0.98-0.98)	0.50
VTE	0.89	0.87	0.90	0.90	0.87	0.88	0.96 (0.96-0.96)	0.52
Stroke	0.89	0.91	0.87	0.88	0.91	0.89	0.96 (0.96-0.96)	0.52

PPV, Positive predictive value; *NPV*, negative predictive value; *AUC*, area under the receiver operating characteristic curve; *CI*, confidence interval; *VTE*, venous thromboembolism.

TABLE E11. Characteristics of subjects (ranked by quadratic chi-distance) correctly classified compared to those misclassified for hemorrhage requiring reoperation

Rank	Variable	Always correctly classified as not having complication, mean ± SD	Always misclassified as having complication, mean ± SD	Rank	Variable	Always correctly classified as having complication, mean ± SD	Always misclassified as not having complication, mean ± SD
1	VentHrsTot	14.93 ± 51.14	123.45 ± 225.93	1	BdFFPU	4.09 ± 5.46	0.47 ± 1.67
2	BdPlatU	0.27 ± 0.87	2.12 ± 3.58	2	BdPlatU	3.15 ± 4.81	0.29 ± 0.70
3	BdFFPU	0.37 ± 1.34	2.74 ± 3.92	3	BdCryoU	1.79 ± 3.42	0.25 ± 1.29
4	ICUInHrs	68.76 ± 81.60	219.79 ± 296.30	4	BdRBCU	9.05 ± 10.13	2.22 ± 1.72
5	BdCryoU	0.18 ± 0.94	1.05 ± 2.52	5	VentHrsTot	113.69 ± 230.95	61.54 ± 139.07
6	PLOS	7.16 ± 4.93	17.17 ± 17.61	6	IBdFFPU	2.71 ± 3.64	1.72 ± 2.66
7	LOS	9.47 ± 30.38	20.90 ± 21.41	7	IBdRBCU	3.48 ± 4.45	2.19 ± 2.39
8	ORDuration	458.59 ± 80.40	401.99 ± 149.26	8	VentHrsA	145.89 ± 300.28	207.80 ± 306.57
9	BdRBCU	1.69 ± 1.24	6.78 ± 7.30	9	ICUInHrs	201.87 ± 306.71	141.50 ± 175.99
10	IBdRBCU	1.67 ± 1.93	3.29 ± 3.87	10	IBdPlatU	1.92 ± 2.74	1.51 ± 2.12
11	IBdFFPU	1.04 ± 1.76	2.56 ± 3.27	11	IBdCryoU	1.37 ± 3.78	1.07 ± 3.16
12	IBdCryoU	0.57 ± 2.05	1.27 ± 3.11	12	ORDuration	394.15 ± 148.83	374.77 ± 187.71
13	IBdPlatU	1.14 ± 1.87	1.85 ± 2.39	13	PLOS	15.09 ± 17.66	12.84 ± 10.51
14	PostCreat	1.40 ± 1.22	2.20 ± 1.74	14	LOS	18.75 ± 21.58	16.11 ± 13.57
15	SIDuration	247.66 ± 86.87	309.85 ± 131.05	15	PCO2	38.02 ± 5.87	38.69 ± 7.11
16	CreatLst	1.16 ± 1.00	1.37 ± 1.23	16	VSMiIm	309.19 ± 69.99	304.05 ± 71.16
17	PerfusTm	110.29 ± 52.32	146.75 ± 79.28	17	TotCircArrTm	37.03 ± 30.68	32.34 ± 19.41
18	WBC	7.96 ± 3.18	8.50 ± 4.28	18	PO2	85.24 ± 31.58	83.06 ± 35.61
19	VSMiImSz	30.12 ± 5.02	29.08 ± 3.65	19	CreatLst	1.30 ± 1.13	1.29 ± 1.16
20	LwstTemp	32.90 ± 3.18	31.96 ± 4.38	20	PostCreat	2.02 ± 1.65	1.86 ± 1.45
21	TotCircArrTm	30.93 ± 26.78	34.88 ± 24.75	21	SIDuration	303.06 ± 133.27	282.67 ± 113.06
22	HighIntraGlu	182.01 ± 53.78	193.40 ± 57.64	22	PerfusTm	143.57 ± 80.80	129.68 ± 66.09
23	LVSD	34.51 ± 9.42	37.50 ± 12.54	23	LVSD	37.64 ± 12.42	36.48 ± 10.64
24	VentHrsA	179.40 ± 243.84	181.97 ± 304.92	24	VSTrImSz	30.01 ± 3.00	30.29 ± 2.62
25	PCO2	38.48 ± 5.49	38.06 ± 6.49	25	POpEF	47.61 ± 17.65	49.16 ± 15.22
26	PASYS	37.30 ± 14.24	42.26 ± 16.77	26	DHCATm	12.92 ± 18.96	13.11 ± 14.86
27	Hct	39.28 ± 5.55	37.37 ± 6.26	27	HighIntraGlu	192.46 ± 59.04	192.34 ± 73.27
28	RFHemoglobin	13.13 ± 2.05	12.40 ± 2.27	28	LwstTemp	32.08 ± 4.30	32.23 ± 4.08
29	HDEF	53.10 ± 12.85	49.35 ± 16.37	29	LVEDD	51.13 ± 10.50	50.35 ± 9.57
30	VSAoIm	317.04 ± 126.42	306.91 ± 115.91	30	WeightKg	84.85 ± 20.12	87.68 ± 22.79
31	LVEDD	48.97 ± 8.61	50.82 ± 10.58	31	RFHemoglobin	12.61 ± 2.25	12.58 ± 2.42
32	VSTrIm	335.21 ± 89.94	322.29 ± 86.09	32	BSA	1.97 ± 0.25	1.99 ± 0.28

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TABLE E11. Continued

Rank	Variable	Always correctly classified as not having complication, mean ± SD	Always misclassified as having complication, mean ± SD	Rank	Variable	Always correctly classified as having complication, mean ± SD	Always misclassified as not having complication, mean ± SD
33	VSMiIm	308.94 ± 73.72	307.67 ± 67.04	33	VSAoImSz	23.53 ± 2.47	23.38 ± 2.76
34	DHCATm	11.67 ± 18.58	12.19 ± 17.54	34	VSMiImSz	29.35 ± 3.69	29.59 ± 4.21
35	POpEF	50.62 ± 14.52	48.21 ± 17.18	35	Platelets	206.49 ± 781.23	211.50 ± 844.32
36	PO2	85.04 ± 37.43	84.52 ± 34.58	36	WBC	8.36 ± 4.58	8.41 ± 3.67
37	Platelets	2167.34 ± 691.55	20,31.61 ± 758.94	37	Age	65.04 ± 12.64	66.22 ± 11.98
38	VSTrImSz	29.90 ± 4.68	30.17 ± 3.63	38	VSAoIm	311.16 ± 125.29	321.44 ± 138.82
39	VSAoImSz	23.52 ± 2.48	23.40 ± 2.46	39	Hct	37.91 ± 6.24	37.84 ± 6.40
40	Age	64.83 ± 11.68	65.70 ± 12.82	40	HDEF	49.66 ± 16.28	50.46 ± 14.61
41	HeightCm	171.76 ± 10.53	171.77 ± 10.68	41	HeightCm	172.19 ± 10.66	171.53 ± 11.85
42	BSA	2.00 ± 0.25	1.97 ± 0.25	42	PASYS	41.67 ± 16.47	42.60 ± 16.48
				43	BdFFPU	324.14 ± 91.69	315.00 ± 76.14

TABLE E12. Characteristics of subjects (ranked by quadratic chi-distance) correctly classified compared to those misclassified for venous thromboembolism

Rank	Variable	Always correctly classified as not having complication	Always misclassified as having complication	Rank	Variable	Always correctly classified as having complication	Always misclassified as not having complication
1	VentHrsTot	10.76 ± 24.09	164.03 ± 262.13	1	VentHrsA	308.83 ± 400.35	83.10 ± 166.11
2	ICUInHrs	59.46 ± 55.04	289.95 ± 322.97	2	VentHrsTot	205.37 ± 325.65	41.22 ± 87.38
3	VentHrsA	51.59 ± 100.11	259.81 ± 324.70	3	ICUInHrs	336.61 ± 382.23	117.78 ± 155.25
4	PLOS	6.29 ± 3.47	24.61 ± 16.60	4	BdFFPU	2.24 ± 5.04	1.04 ± 2.62
5	LOS	8.44 ± 30.85	29.34 ± 20.41	5	BdRBCU	7.03 ± 9.14	3.33 ± 4.00
6	ORDuration	463.38 ± 82,613.65	403.10 ± 136.23	6	IBdFFPU	2.64 ± 3.46	1.93 ± 4.70
7	BdPlatU	0.57 ± 1.63	1.32 ± 3.27	7	BdPlatU	1.83 ± 4.75	0.95 ± 2.09
8	BdRBCU	2.20 ± 3.02	5.79 ± 7.15	8	IBdPlatU	2.05 ± 3.35	1.34 ± 1.94
9	BdFFPU	0.74 ± 2.14	1.77 ± 3.81	9	DHCATm	11.21 ± 16.88	5.64 ± 9.95
10	IBdRBCU	1.71 ± 2.20	2.96 ± 3.26	10	IBdRBCU	3.39 ± 4.28	2.32 ± 3.06
11	IBdFFPU	1.10 ± 1.98	2.22 ± 2.78	11	IBdCryoU	1.57 ± 3.50	0.89 ± 2.55
12	IBdCryoU	0.61 ± 2.30	1.21 ± 2.76	12	BdCryoU	0.71 ± 2.40	0.54 ± 1.83
13	IBdPlatU	1.17 ± 1.95	1.70 ± 2.09	13	PostCreat	2.44 ± 1.87	1.79 ± 1.86
14	BdCryoU	0.37 ± 1.60	0.54 ± 1.76	14	VSTrIm	328.30 ± 93.14	342.95 ± 77.63
15	PostCreat	1.36 ± 1.16	2.34 ± 1.78	15	LwstTemp	31.42 ± 5.01	32.77 ± 3.31
16	WBC	7.87 ± 3.19	9.16 ± 4.14	16	PerfusTm	147.32 ± 77.74	127.92 ± 65.76
17	PerfusTm	110.17 ± 53.34	139.97 ± 70.99	17	PCO2	37.75 ± 6.54	37.97 ± 4.94
18	SIDuration	246.23 ± 87.72	307.93 ± 118.87	18	CreatLst	1.38 ± 1.27	1.25 ± 1.03
19	VSMiImSz	30.22 ± 5.13	28.87 ± 3.29	19	LVSD	38.62 ± 13.25	36.29 ± 10.25
20	CreatLst	1.15 ± 0.99	1.37 ± 1.20	20	SIDuration	322.92 ± 131.47	278.51 ± 117.37
21	LwstTemp	32.93 ± 3.13	31.94 ± 4.46	21	ORDuration	421.45 ± 148.92	365.69 ± 128.02
22	VSTrIm	334.90 ± 90.91	328.29 ± 87.93	22	VSAoIm	306.71 ± 128.20	312.79 ± 124.23
23	HDEF	53.51 ± 12.57	47.36 ± 16.64	23	LVEDD	51.29 ± 11.24	50.45 ± 9.03
24	LVSD	34.32 ± 9.23	38.02 ± 12.62	24	WBC	9.23 ± 4.56	8.58 ± 4.86
25	PCO2	38.50 ± 5.43	37.96 ± 6.51	25	VSMiIm	301.46 ± 63.59	305.09 ± 72.70
26	PO2	85.31 ± 37.63	82.42 ± 30.46	26	PO2	82.08 ± 27.71	84.09 ± 32.85
27	Hct	39.46 ± 5.47	36.72 ± 6.36	27	Age	64.14 ± 13.34	67.04 ± 11.94
28	HighIntraGlu	181.63 ± 54.25	194.46 ± 55.13	28	HDEF	46.96 ± 16.93	50.08 ± 15.43
29	PASYS	36.98 ± 14.15	42.54 ± 16.23	29	VSAoImSz	23.52 ± 2.47	23.21 ± 2.44
30	RFHemoglobin	13.20 ± 2.03	12.14 ± 2.26	30	POpEF	50.36 ± 15.95	48.13 ± 15.15
31	LVEDD	48.89 ± 8.53	50.92 ± 10.59	31	PASYS	42.27 ± 15.71	40.84 ± 15.20
32	Platelets	215.73 ± 68.52	210.84 ± 78.46	32	VSMiImSz	28.88 ± 2.91	29.44 ± 3.12
33	VSMiIm	309.59 ± 74.54	305.97 ± 63.26	33	WeightKg	88.29 ± 21.79	87.72 ± 21.44
34	POpEF	51.14 ± 14.35	49.30 ± 16.04	34	RFHemoglobin	12.12 ± 2.34	12.74 ± 2.67
35	VSAoIm	317.20 ± 126.96	304.41 ± 109.76	35	Hct	36.64 ± 6.58	38.38 ± 6.57
36	DHCATm	12.11 ± 19.52	10.60 ± 14.53	36	HeightCm	171.83 ± 10.75	171.32 ± 10.63
37	VSTrImSz	29.97 ± 5.05	30.02 ± 2.80	37	BSA	2.00 ± 0.26	1.99 ± 0.26
38	VSAoImSz	23.53 ± 2.48	23.39 ± 2.46	38	Platelets	209.71 ± 82.09	219.24 ± 88.63
39	WeightKg	87.88 ± 20.29	87.95 ± 21.56				
40	Age	64.75 ± 11.64	65.12 ± 13.26				
41	BSA	2.00 ± 0.25	2.00 ± 0.26				
42	HeightCm	171.85 ± 10.53	171.55 ± 10.52				

TABLE E13. Characteristics of subjects (ranked by quadratic chi-distance) correctly classified compared to those misclassified for stroke

Rank	Variable	Always correctly classified as not having complication	Always misclassified as having complication	Rank	Variable	Always correctly classified as having complication	Always misclassified as not having complication
1	VentHrsTot	10.07 ± 26.18	129.67 ± 225.60	1	ORDuration	396.18 ± 144.13	1347.33 ± 219.66
2	ICUInHrs	58.26 ± 56.51	242.58 ± 286.11	2	VentHrsTot	169.91 ± 259.96	35.07 ± 86.54
3	PLOS	6.46 ± 3.80	17.95 ± 15.74	3	ICUInHrs	274.81 ± 321.21	101.91 ± 113.17
4	VentHrsA	71.02 ± 157.28	229.97 ± 291.23	4	PLOS	19.07 ± 19.28	9.99 ± 7.49
5	BdPlatU	0.53 ± 1.45	1.31 ± 3.31	5	VentHrsA	262.25 ± 336.95	92.82 ± 135.38
6	LOS	8.83 ± 31.87	20.57 ± 17.23	6	BdFFPU	1.94 ± 4.99	1.01 ± 2.02
7	ORDuration	467.93 ± 84,550.51	381.52 ± 129.84	7	LOS	21.58 ± 20.88	12.99 ± 10.72
8	BdRBCU	2.14 ± 2.53	5.24 ± 7.34	8	BdPlatU	1.56 ± 4.27	0.85 ± 2.28
9	BdFFPU	0.70 ± 1.76	1.66 ± 4.19	9	IBdFFPU	2.40 ± 3.18	1.77 ± 3.06
10	IBdRBCU	1.69 ± 2.21	2.71 ± 2.97	10	DHCATm	14.03 ± 18.96	8.25 ± 11.47
11	IBdFFPU	1.10 ± 1.94	1.93 ± 2.72	11	BdRBCU	5.69 ± 8.40	3.33 ± 3.95
12	IBdPlatU	1.17 ± 1.89	1.56 ± 2.17	12	TotCircArrTm	38.52 ± 31.43	29.33 ± 22.07
13	BdCryoU	0.34 ± 1.45	0.52 ± 1.84	13	IBdCryoU	1.35 ± 3.17	1.14 ± 4.05
14	IBdCryoU	0.61 ± 2.28	0.97 ± 2.46	14	BdCryoU	0.63 ± 2.22	0.41 ± 1.20
15	PostCreat	1.36 ± 1.17	2.07 ± 1.63	15	IBdRBCU	3.08 ± 3.67	2.26 ± 2.80
16	DHCATm	11.45 ± 19.29	12.64 ± 16.28	16	IBdPlatU	1.92 ± 2.91	1.56 ± 1.99
17	CreatLst	1.15 ± 1.00	1.29 ± 1.07	17	PostCreat	2.15 ± 1.79	1.81 ± 1.53
18	PerfusTm	108.99 ± 51.93	138.16 ± 71.37	18	LwstTemp	30.72 ± 5.59	32.52 ± 3.72
19	SIDuration	245.55 ± 86.41	294.07 ± 115.73	19	VSTrImSz	30.02 ± 6.65	29.63 ± 2.44
20	WBC	7.88 ± 3.16	8.72 ± 3.84	20	WBC	9.08 ± 4.39	8.40 ± 3.80
21	VSTrIm	335.57 ± 92.09	323.94 ± 81.87	21	PerfusTm	147.10 ± 78.96	122.27 ± 62.94
22	LwstTemp	32.97 ± 3.08	31.81 ± 4.52	22	VSMiImSz	28.88 ± 3.82	29.90 ± 6.78
23	VSMiImSz	30.29 ± 5.16	28.87 ± 3.51	23	SIDuration	308.21 ± 128.23	267.94 ± 105.47
24	HighIntraGlu	180.96 ± 53.55	193.39 ± 56.53	24	HighIntraGlu	198.29 ± 60.93	190.29 ± 80.12
25	VSMiIm	309.54 ± 74.84	306.55 ± 65.51	25	PO2	87.01 ± 48.93	85.79 ± 38.70
26	PO2	85.11 ± 36.75	84.12 ± 38.34	26	WeightKg	84.34 ± 19.66	89.24 ± 23.73
27	HDEF	53.29 ± 12.76	50.77 ± 14.61	27	VSMiIm	308.25 ± 72.33	308.05 ± 84.92
28	PCO2	38.50 ± 5.42	38.11 ± 5.98	28	RFHemoglobin	12.58 ± 2.18	12.65 ± 2.51
29	VSAoImSz	23.59 ± 2.48	23.12 ± 2.45	29	Platelets	213.30 ± 75.32	216.24 ± 81.20
30	LVSD	34.57 ± 9.50	35.15 ± 10.54	30	BSA	1.95 ± 0.25	2.00 ± 0.28
31	Hct	39.42 ± 5.54	37.86 ± 5.81	31	VSTrIm	321.92 ± 84.61	317.90 ± 75.70
32	PASYS	37.08 ± 14.28	39.90 ± 15.07	32	POpEF	50.67 ± 15.33	48.35 ± 15.33
33	VSTrImSz	29.97 ± 4.54	29.85 ± 4.28	33	CreatLst	1.31 ± 1.07	1.28 ± 1.11
34	HeightCm	172.14 ± 10.49	169.93 ± 10.55	34	Hct	37.85 ± 5.92	37.98 ± 6.31
35	POpEF	50.62 ± 14.66	50.06 ± 15.62	35	HeightCm	170.26 ± 10.65	171.16 ± 12.71
36	Platelets	215.69 ± 69.19	213.22 ± 71.39	36	LVSD	35.27 ± 10.42	35.95 ± 9.99
37	VSAoIm	315.53 ± 125.37	316.30 ± 124.27	37	Age	66.52 ± 12.05	66.92 ± 12.07
38	LVEDD	49.12 ± 8.70	48.62 ± 9.17	38	PASYS	39.84 ± 15.07	40.53 ± 14.97
39	WeightKg	88.53 ± 20.54	84.19 ± 19.40	39	VSAoImSz	23.28 ± 2.52	23.57 ± 2.56
40	Age	64.30 ± 11.80	67.97 ± 11.24	40	LVEDD	48.79 ± 9.10	50.20 ± 9.19
				41	HDEF	50.67 ± 14.97	50.57 ± 14.85
				42	VSAoIm	320.59 ± 124.03	320.26 ± 132.77