Guiding Aortic Arch Repair Decision Making: An Application of Machine Learning

Objective: Using machine learning, to model the risk of death or stroke in elective aortic arch surgery based upon patient characteristics and intraoperative decisions.

Methods: 1411 patients from 9 institutions who had elective aortic arch procedure between 2008 and 2021 were included. 44 preoperative and 30 intraoperative variables were used in modelling risk of patient death and stroke at 30 days. After splitting the data into 80% training and 20% test, Logistic Regression and XgBoost models were trained, tested and compared in discrimination. To understand the importance of intraoperative decisions in machine learning modelling, Shapely Additive Explanations (SHAP) values were generated and studied.

Results: Overall, 4.1% (58/1411) of patients died and 5.6% (79/1411) of patients experienced stroke. On the test data, for death, XgBoost (AUC: 0.81, sensitivity: 0.73, specificity: 0.82) demonstrated better discrimination than Logistic Regression (AUC: 0.75, sensitivity: 0.55, specificity: 0.80) (Figure). For predicting stroke, XgBoost discrimination (AUC: 0.91, sensitivity: 0.92, specificity: 0.70) was improved over Logistic Regression (AUC: 0.75, sensitivity: 0.62, specificity: 0.75). XgBoost produced a net reclassification improvement of 0.20 and 0.26 for death and stroke. From SHAP interpretative analysis, intraoperative decisions are 9 of the top 20 predictors of death and 8 of the top 20 predictors for stroke. The important intraoperative decisions that impact death and stroke are cerebral perfusion strategy, hypothermia temperature and cannulation site. Antegrade cerebral perfusion reduced the risk of death and stroke. Aortic cannulation reduced the risk of death while axillary and aortic cannulation reduced the risk of stroke. Deep hypothermia reduced the risk of stroke but not the risk of death, though mild hypothermia is associated with poor outcome. The magnitude of these relationships is patient specific based on their preoperative characteristics and other intraoperative decisions.

Conclusions: Machine learning is excellent in predicting risk of death or stroke during elective aortic arch surgery. Using machine learning, we can more accurately identify those at risk for death or stroke. On a patient level, we can tailor our operative decision making based on a patient's specific characteristics. This allows us to personalize arch surgery to maximize benefit for patients while reducing the risks of perioperative adverse event.

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Figure. AUC curves and SHAP values showing intraoperative decisions impacting death and stroke.