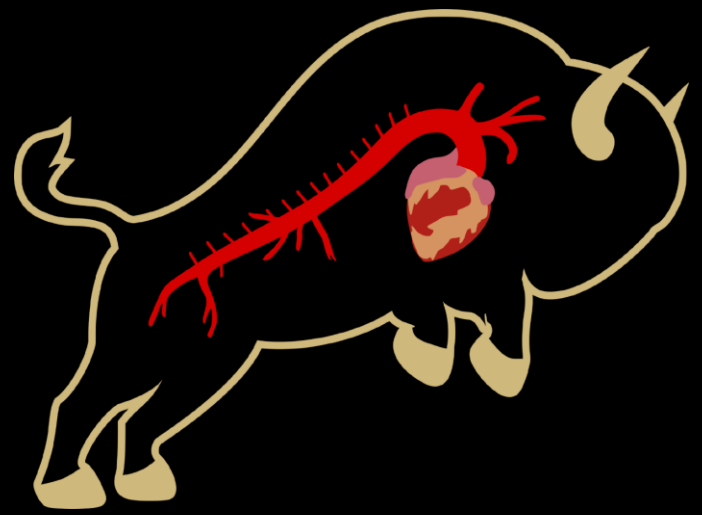
Predicting Renal Replacement Therapy After Total Arch Surgery Using Machine Learning

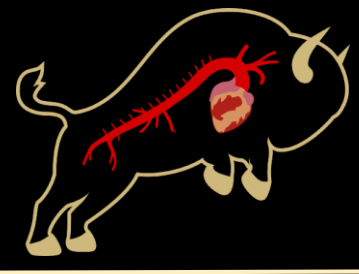
Adam Carroll (1), Nicolas Chanes (1), Michael Kirsch (1), Bo Chang Wu (1), Muhammad Aftab (1), T. Brett Reece (1)

(1) University of Colorado Anschutz, Denver, CO

No disclosures



Introduction



- Patients undergoing total arch surgery are at high risk of acute kidney injury (AKI)
  - AKI significantly increases morbidity and mortality

- Identifying patients at risk for AKI in total arch surgery may help to improve outcomes

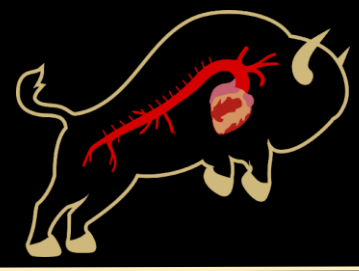
Aim

- Develop a machine learning model to predict need for renal replacement therapy after total arch surgery
- Determine if specific features are associated with increased risk of AKI in total arch surgery

Methods

- Retrospective review of aortic database for all patients who underwent total arch surgery from 2009 to 2022
- Patients divided into training (70%) and testing (30%) sets with eXtreme gradient boosting (XGBoost) models
- Included 64 input parameters
  - 24 demographic characteristics
  - 8 pre-operative, 32 intraoperative variables
- Assess model performance and accuracy with area under receiver operating curve (AUC-ROC) and precision with area under precision recall curve (AUC-PR, mean average precision)
- Perform feature analysis to determine impact of input parameters

Results



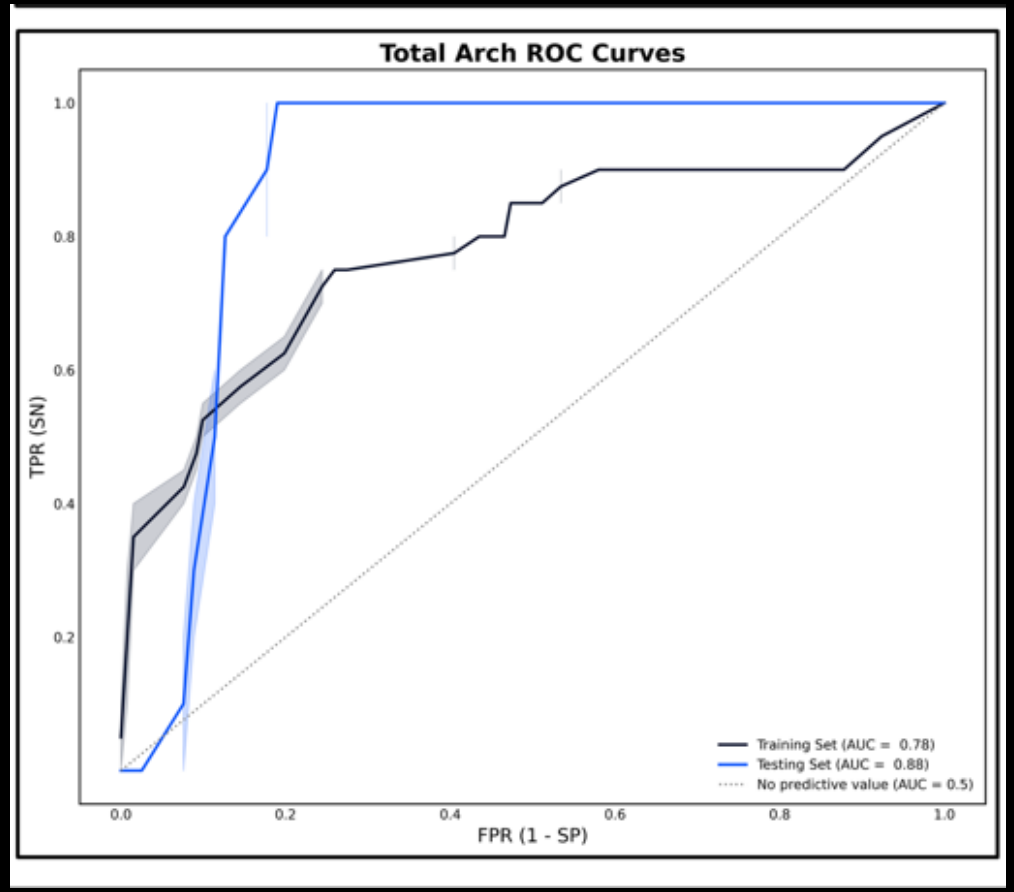
- 235 patients included in analysis
- Majority of patients Caucasian, presented urgently or emergently with dissection pathology
- Most patients required distal extension with elephant trunk
- AKI requiring renal replacement therapy (RRT) occurred in 25 patients (10.6%)

Age	59 ± 14
Male	153 (65.1%)
BMI	28 ± 6
Baseline Systolic BP	135 ± 25
Baseline Diastolic BP	77 ± 17
Race	
Caucasian	168 (71.5%)
African American	29 (12.3%)
Asian	8 (3.4%)
Hispanic	22 (9.4%)
Other	8 (3.4%)
Comorbidities	
No Comorbidities	7 (3.0%)
Dyslipidemia	75 (31.9%)
HTN	181 (77.0%)
Smoking	57 (24.3%)
Diabetes	17 (7.2%)
Renal Disease	30 (12.8%)
PVD	15 (6.4%)
Obesity	73 (31.1%)
CVA	31 (13.2%)
Liver Disease	1 (0.4%)
Pulmonary Disease	60 (25.5%)
CAD	24 (10.2%)
Afib	14 (6.0%)
Autoimmune Disease	8 (3.4%)
Surgical History	
No Hx of CT Surgery	416 (69.1%)
Hx of Sternotomy	67 (11.1%)
Hx of Aortic Surgery	49 (8.1%)
Number of Sternotomies	64 (10.6%)
Aortic Presentation	
Aneurysm	133 (56.6%)
Dissection	154 (65.5%)
Dissection – Malperfusion	42 (17.9%)
Penetrating Ulcer	5 (2.1%)
Thrombus	5 (2.1%)
Infection	1 (0.4%)
Endoleak	3 (1.3%)
Baseline Labs	
Creatinine	1 ± 1
HbA1c	6 ± 1
Hemoglobin	13 ± 2
Platelets	220 ± 80
INR	1 ± 0

Procedure Type	
Total Arch	235 (100%)
Root + Total Arch	65 (27.7%)
Open Arch Elephant Trunk	178 (75.7%)
Operative Urgency	
Elective	111 (47.2%)
Urgent/Emergent	124 (52.8%)
Adjunctive Procedure	
No Adjunctive Structural Procedure	93 (39.6%)
Aortic Valve Repair	9 (3.8%)
Aortic Valve Replacement	35 (14.9%)
Mitral Valve Repair	2 (0.9%)
Tricuspid Valve Repair	2 (0.9%)
PFO Closure	3 (1.3%)
VSD Closure	2 (0.9%)
Afib Procedure	3 (1.3%)
CABG	11 (4.7%)
Operative Variables	
Nadir Bladder Temperature	25 ± 3
CPB Time	200 ± 73
Aortic Cross-Clamp Time	103 ± 58
Circulatory Arrest Time	27 ± 16
OR CPB Nadir Hemoglobin	8 ± 1
Circulatory Arrest Protection	
Straight HCA	6 (2.6%)
RCP	14 (6.0%)
SACP via Axillary	34 (14.5%)
SACP via Innominate	47 (20.0%)
Direct Innominate	1 (0.4%)
Innominate, Left Carotid	41 (17.4%)
Intraoperative Blood Products	
Intraoperative # RBC Units	4 ± 5
Intraoperative # FFP Units	6 ± 5
Intraoperative # PLT Units	2 ± 1
Intraoperative # Cryo Units	0 ± 1

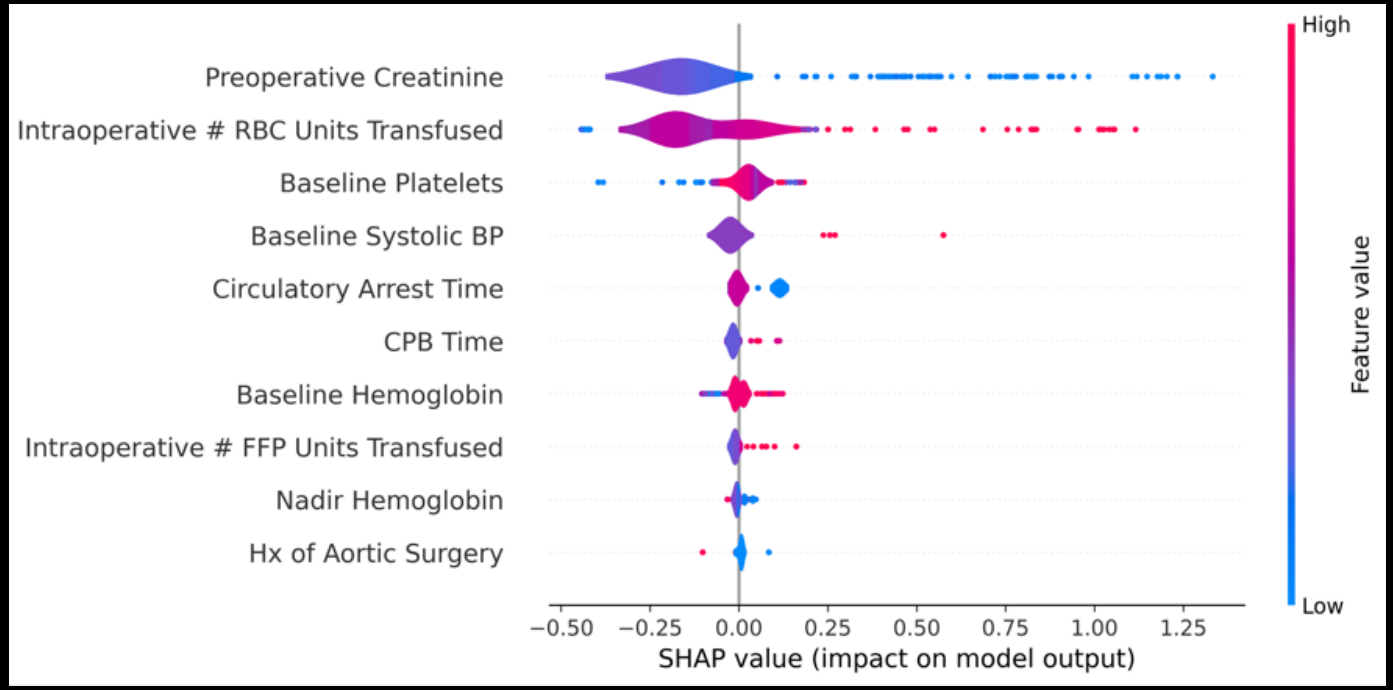
Results

- XG boost model demonstrated excellent accuracy (AUC-ROC 0.88 for testing set)
  - Predictor with 92% accuracy on testing data set
  - Brier Score 0.10



Results: Feature Impact & Value

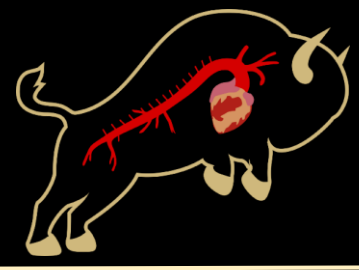
- SHAP-Violin plot provides insight into model decision making
- Low pre-operative creatinine levels associated with increased AKI risk
  - May be an indicator of baseline frailty
- Increased intraoperative transfusion, longer cardiopulmonary bypass time associated with increased risk of RRT



Interpreting SHAP Violin plot:

- Descending order of impact on model (highest=most impact)
- Color indicates variable value (for categorical variables, yes=high)

Conclusions



- Machine learning model demonstrated excellent performance in predicting patients who would have severe AKI requiring RRT after total arch surgery
- Lower pre-operative creatinine, likely indicating frailty, length of cardiopulmonary bypass, and increased intraoperative RBC administration associated with increased AKI risk
- Predicting which patients are at risk for AKI may help to guide clinical decision making

Questions???