Supplementary Online Content

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This supplementary material has been provided by the authors to give readers additional information about their work.
### Study Sample

**Inclusion Criteria:** Individuals (1) age 18 or greater; (2) recorded inpatient hospital admission; (3) undergoing a major noncardiac surgery

**Exclusion Criteria:** Individuals with (1) multiple major surgeries during hospitalization; (2) did not have at least one preoperative and postoperative serum creatinine (SCr) measurement; (3) end stage renal disease (ESRD) undergoing dialysis within the past year*; (4) high baseline SCr of 4.5 mg/dl or greater (because clinical criteria for AKI based on SCr elevation may not apply to these patients); or (5) experienced acute kidney injury up to seven days before surgery

### CONSORT Diagram

#### Abbreviations:
- SCr, serum creatinine
- ESRD, End stage renal disease
- KDIGO, Kidney Disease: Improve Global Outcomes
- RIFLE, Risk, Injury, Failure, Loss of kidney function, End stage kidney disease
- AKIN, Acute Kidney Injury Network

*Exclusion criteria: Billing Codes for ESRD undergoing Dialysis*

Patients were excluded from the study if they previously had a diagnosis or billing code within 1 year of index hospitalization.

### ICD-9-CM Diagnosis Codes
- 585.6 End stage renal disease
- 996.81 Complications of transplanted kidney
- V42.0 Kidney replaced by transplant
- V45.1 Postsurgical renal dialysis status
- V56.0 Encounter for extracorporeal dialysis
- V56.1 Fitting and adjustment of extracorporeal dialysis catheter
- V56.2 Fitting and adjustment of peritoneal dialysis catheter
- V56.3 Encounter for adequacy testing for dialysis
- V56.31 Encounter for adequacy testing for hemodialysis
- V56.32 Encounter for adequacy testing for peritoneal dialysis
- V56.8 Encounter for other dialysis
- E879.1 Kidney dialysis as the cause of abnormal reaction of patient, or of later complication, without mention of misadventure at time of procedure

### ICD-10-CM Diagnosis Codes
- T86.10 Unspecified complication of kidney transplant
- T86.11 Kidney transplant rejection
- T86.12 Kidney transplant failure
- T86.13 Kidney transplant infection
- T86.19 Other complication of kidney transplant
- Z99.2 Dependence on renal dialysis

### CPT Procedure Codes
- 90935 Hemodialysis one evaluation
- 90937 Hemodialysis repeated eval
- 90940 Hemodialysis access study
- 90945 Dialysis one evaluation

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Secondary Outcomes
Secondary outcomes included inpatient dialysis, a post-surgical length of stay $\geq 7$ days (to reflect a prolonged post-surgical stay), and all-cause in-hospital death. Inpatient dialysis was identified if a procedure code in the list below was present during index hospitalization. The post-surgical length of stay threshold of $\geq 7$ days was selected as a marker for prolonged length of stay. In the absence of a well-defined threshold in the literature, we selected 7 days after surgery because it aligned with our post-operative AKI definition (which was defined up to 7 days after surgery). All-cause in-hospital death was defined as patient death anytime between the end of surgery and before discharge of index hospitalization.

Inpatient Dialysis Procedure Codes
ICD-9-PCS Procedure Codes
39.95 Hemodialysis

ICD-10-PCS Procedure Codes
5A1D60Z Performance of Urinary Filtration, Multiple
5A1D70Z Performance of Urinary Filtration, Intermittent, Less than 6 Hours Per Day
5A1D00Z Performance of Urinary Filtration, Single
5A1D90Z Performance of Urinary Filtration, Continuous, Greater than 18 hours Per Day
5A1D80Z Performance of Urinary Filtration, Prolonged Intermittent, 6-18 hours Per Day
Sensitivity Analyses
We tested the sensitivity of our results to several data and modeling decisions.

1) Ensembling Models - Super Learner
In response to an editor’s comment, we examined the performance difference between our models and an ensemble technique like Super Learner, which are beginning to become more common. Algorithms chosen for analysis were penalized logistic regression (glmnet), gradient boosting machine (gbm), XGboost (xgboost), and random forest (randomForest).

2) Alternate Method Handling for Extreme and Artifact Values
In response to an editor’s comment, we test whether results were sensitive to treating outlier and extreme variable data as missing instead of our main approach. Values below the 1st percentile and values greater than the 99th percentile were set to missing for this analysis. All modeling and analysis were consistent otherwise.

3) Surgical Subgroup Analysis
In response to a reviewer comment, we examine if model performance differed by surgical specialty-specific models. Models were trained and tested in each respective subgroups. Results were compared to the main analysis.

4) Alternate Acute Kidney Injury Definitions
To address multiple definitions of AKI by professional societies, we also used two other definitions: (1) Risk, Injury, and Failure; and Loss; and End-stage kidney disease (RIFLE) classification of risk—developed by Acute Dialysis Quality Initiative—was defined as an increase of SCr by 1.5 times, or estimated glomerular filtration rate (eGFR) decrease by 25%, and (2) Acute Kidney Injury Network (AKIN) stage 1 was defined as an absolute increase in serum creatinine by 0.3 mg/dl (26.4 μmol/l) or a 50% increase in serum creatinine (i.e. 1.5-fold from baseline).

eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation. Models for main analysis will be reproduced with the two alternate definitions of AKI.

5) High Risk Stratification Cutoff Analysis
Given the lack of an evidence-based definition of a high-risk probability value for AKI, the top 20% was arbitrarily selected and we examined sensitivity to cutoff by used top 10% and top 30%.
eAppendix. Variables

A total of 339 baseline, preoperative, and intraoperative variables were constructed. Final models in main and sensitivity analyses were derived using a set of components of these variables. All categorical variables were one-hot encoded to unique binary variables.

Baseline Variables (35)
Age, sex, marital status, race, insurance, Elixhauser comorbidities (30)\(^6\)

Preoperative Variables (274)
Last known laboratory measurement value up to 30 days (26; NT-proBNP, creatine kinase, GFR non-African American, glucose POC, glucose level, sodium level, potassium level, chloride level, creatinine level, blood urea nitrogen, bicarbonate venous, whole blood glucose, hemoglobin, hematocrit, white blood cell, red blood cell, platelet count, alanine aminotransferase, bilirubin total, aspartate aminotransferase, alkaline phosphatase, bilirubin direct, bilirubin indirect, international normalization ratio, prothrombin time, partial thromboplastin time); labs ordered (2; troponin-I point of care, troponin-T); ASA physical status; Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project’s Clinical Classification Software for Procedures (244)\(^7\); High Risk Surgery\(^8\)

Intraoperative Variables (30)
Time to surgery (min); surgery duration (min); urine output (ml); total of crystalloid administration (ml); estimated blood loss (ml); arterial line placement; Minutes under mean arterial pressure of 50; Minutes under mean arterial pressure of 60; Intraoperative fluid administration (5; platelets, fresh frozen plasma, packed red blood cells, salvaged red blood cells, whole blood autologous); Total dose medication in milligrams (5; epinephrine, phenylephrine, norepinephrine, ephedrine, vasopressin); Intraoperative medication administration (3; sodium bicarbonate, atropine, calcium chloride); Lowest recorded vital sign value (4; heart rate, mean arterial pressure, systolic blood pressure, diastolic blood pressure); Highest recorded vital sign value (4; heart rate, mean arterial pressure, systolic blood pressure, diastolic blood pressure); Mean (calculated) vital sign value (4; heart rate, mean arterial pressure, systolic blood pressure, diastolic blood pressure); Delta (Highest – Lowest) vital sign value (3; heart rate, systolic blood pressure, diastolic blood pressure)
### eTable 1. Rates of Missing Data in Variables

The number of observations with missing data for variables were calculated in the study sample (n = 42,615). The table below shows the number of observations with missing data only for the variables that contain missing data.

| Source      | Variable                          | Data Type   | Number of Observations with Missing Values | % Observations with Missing Values |
|-------------|-----------------------------------|-------------|--------------------------------------------|-----------------------------------|
| Preoperative | NT-proBNP                        | continuous  | 40,227                                    | 98.6                              |
| Preoperative | Creatine Kinase                  | continuous  | 39,900                                    | 97.8                              |
| Preoperative | GFR Non-African American         | continuous  | 11,716                                    | 28.7                              |
| Preoperative | Glucose POC                      | continuous  | 39,650                                    | 97.2                              |
| Preoperative | Glucose Level                    | continuous  | 3,396                                     | 8.8                               |
| Preoperative | Sodium Level                     | continuous  | 4,109                                     | 10.1                              |
| Preoperative | Potassium Level                  | continuous  | 4,248                                     | 10.4                              |
| Preoperative | Chloride Level                   | continuous  | 4,265                                     | 10.5                              |
| Preoperative | Creatinine Level                 | continuous  | 4,063                                     | 10.0                              |
| Preoperative | Blood Urea Nitrogen              | continuous  | 4,078                                     | 10.0                              |
| Preoperative | Bicarbonate Venous               | continuous  | 37,846                                    | 92.8                              |
| Preoperative | Whole Blood Glucose              | continuous  | 38,227                                    | 93.7                              |
| Preoperative | Hemoglobin                       | continuous  | 3,911                                     | 9.6                               |
| Preoperative | Hematocrit                        | continuous  | 3,909                                     | 9.6                               |
| Preoperative | White Blood Cell                 | continuous  | 4,271                                     | 10.5                              |
| Preoperative | Red Blood Cell                   | continuous  | 4,268                                     | 10.5                              |
| Preoperative | Platelet Count                   | continuous  | 3,988                                     | 9.8                               |
| Preoperative | Alanine Aminotransferase         | continuous  | 18,206                                    | 44.6                              |
| Preoperative | Bilirubin Total                  | continuous  | 18,150                                    | 44.5                              |
| Preoperative | Aspartate Aminotransferase       | continuous  | 18,216                                    | 44.7                              |
| Preoperative | Alkaline Phosphatase             | continuous  | 18,171                                    | 44.6                              |
| Preoperative | Bilirubin Direct                 | continuous  | 34,135                                    | 83.7                              |
| Preoperative | Bilirubin Indirect               | continuous  | 34,170                                    | 83.8                              |
| Preoperative | International Normalization Ratio| continuous  | 8,473                                     | 20.8                              |
| Preoperative | Prothrombin Time                 | continuous  | 8,475                                     | 20.8                              |
| Preoperative | Partial Thromboplastin Time      | continuous  | 8,948                                     | 21.9                              |
| Intraoperative | Max estimated blood loss       | continuous  | 9,410                                     | 23.1                              |
| Intraoperative | Max urine output                | continuous  | 15,784                                    | 38.7                              |
| Intraoperative | Min heart rate                  | continuous  | 23                                        | 0.1                               |
| Intraoperative | Max heart rate                  | continuous  | 23                                        | 0.1                               |
| Intraoperative | Mean heart rate                 | continuous  | 23                                        | 0.1                               |
| Intraoperative | Delta heart rate                | continuous  | 23                                        | 0.1                               |
| Intraoperative | Min systolic blood pressure     | continuous  | 369                                       | 0.9                               |
| Intraoperative | Max systolic blood pressure     | continuous  | 369                                       | 0.9                               |
| Intraoperative | Mean systolic blood pressure    | continuous  | 369                                       | 0.9                               |
| Intraoperative | Delta systolic blood pressure   | continuous  | 369                                       | 0.9                               |
| Intraoperative | Min diastolic blood pressure    | continuous  | 376                                       | 0.9                               |
| Intraoperative | Max diastolic blood pressure    | continuous  | 376                                       | 0.9                               |
| Intraoperative | Mean diastolic blood pressure   | continuous  | 376                                       | 0.9                               |
| Intraoperative | Delta diastolic blood pressure  | continuous  | 376                                       | 0.9                               |
| Intraoperative | Min mean arterial pressure      | continuous  | 21                                        | 0.1                               |
| Intraoperative | Max mean arterial pressure      | continuous  | 21                                        | 0.1                               |
| Intraoperative | Mean mean arterial pressure     | continuous  | 21                                        | 0.1                               |
| Intraoperative | Minutes under mean arterial pressure of 60mmHg | continuous  | 21 | 0.1 |
| Elixhauser Comorbidity | AIDS HIV | binary | 244 | 0.6 |
| Elixhauser Comorbidity | Alcohol abuse | binary | 244 | 0.6 |
| Elixhauser Comorbidity | Blood loss anemia | binary | 244 | 0.6 |
| Elixhauser Comorbidity | Cardiac arrhythmias | binary | 244 | 0.6 |
| Elixhauser Comorbidity | Chronic pulmonary disorders | binary | 244 | 0.6 |

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| Elixhauser Comorbidity                      | Coagulopathy                      | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Congestive heart failure          | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Deficiency anemia                 | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Depression                        | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Diabetes, complicated             | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Diabetes, uncomplicated           | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Drug abuse                        | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Fluid and electrolyte disorders   | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Hypertension, complicated         | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Hypertension, uncomplicated       | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Hypothyroidism                    | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Liver disease                     | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Lymphoma                          | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Metastatic cancer                 | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Obesity                            | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Other neurological disorders       | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Paralysis                          | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Peptic ulcer disease              | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Peripheral vascular disorders      | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Psychoses                          | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Pulmonary circulation             | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Rheumatoid arthritis/collagen vascular disease | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Solid tumor without metastasis    | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Valvular disease                   | binary | 244 | 0.6 |
| Elixhauser Comorbidity                      | Weight loss                        | binary | 244 | 0.6 |
### eTable 2. Extended Clinical Outcomes in the Model Derivation, Validation, and Test Sets

Primary and secondary clinical outcomes of the 42,615 patients who underwent major noncardiac surgery.

| Clinical Outcome                        | All Visits (n = 42,615) | Derivation (n = 25,616) | Validation (n = 8,505) | Test (n = 8,494) |
|----------------------------------------|-------------------------|-------------------------|------------------------|-----------------|
| KDIGO Acute Kidney Injury, No. (%)     | 4,318 (10.1)            | 2,655 (10.4)            | 818 (9.6)              | 845 (10)        |
| RIFLE Acute Kidney Injury, No. (%)     | 4,206 (9.9)             | 2,543 (9.9)             | 806 (9.5)              | 857 (10.1)      |
| AKIN Acute Kidney Injury, No. (%)      | 4,177 (9.8)             | 2,574 (10.1)            | 784 (9.2)              | 819 (9.6)       |
| Inpatient Dialysis, No. (%)            | 103 (0.2)               | 54 (0.2)                | 17 (0.2)               | 32 (0.4)        |
| Prolonged Length of Stay, No. (%)      | 8,335 (19.6)            | 5,032 (19.6)            | 1,634 (19.2)           | 1,669 (19.7)    |
| In-Hospital Death, No. (%)             | 255 (0.6)               | 157 (0.6)               | 40 (0.5)               | 58 (0.7)        |

**Abbreviations:** KDIGO, Kidney Disease: Improve Global Outcomes; RIFLE, Risk, Injury, Failure, Loss of kidney function, End stage kidney disease; AKIN, Acute Kidney Injury Network
**Table 3. Full Model Performance in the Model Derivation, Validation, and Test Sets**

| Models                                      | Derivation Set (n = 25,616), AUC (95% CI) | Validation Set (n = 8,505), AUC (95% CI) | Test Set (n = 8,494), AUC (95% CI) |
|---------------------------------------------|-------------------------------------------|------------------------------------------|-------------------------------------|
| Logistic Regression with Elastic Net Selection |                                           |                                          |                                     |
| Prehospitalization                          | 0.695 (0.685, 0.706)                      | 0.706 (0.687, 0.725)                     | 0.700 (0.681, 0.719)               |
| Preoperative                                | 0.765 (0.756, 0.775)                      | 0.779 (0.762, 0.796)                     | 0.782 (0.765, 0.799)               |
| Perioperative                               | 0.777 (0.767, 0.786)                      | 0.784 (0.767, 0.801)                     | 0.790 (0.773, 0.807)               |
| Random Forest                               |                                           |                                          |                                     |
| Prehospitalization                          | 0.740 (0.731, 0.750)                      | 0.712 (0.693, 0.730)                     | 0.710 (0.691, 0.728)               |
| Preoperative                                | 0.924 (0.920, 0.928)                      | 0.789 (0.771, 0.807)                     | 0.787 (0.769, 0.803)               |
| Perioperative                               | 0.951 (0.948, 0.954)                      | 0.805 (0.789, 0.820)                     | 0.808 (0.792, 0.824)               |
| Gradient Boosting Machine                   |                                           |                                          |                                     |
| Prehospitalization                          | 0.725 (0.714, 0.735)                      | 0.713 (0.694, 0.731)                     | 0.712 (0.695, 0.731)               |
| Preoperative                                | 0.825 (0.817, 0.833)                      | 0.803 (0.787, 0.819)                     | 0.804 (0.788, 0.819)               |
| Perioperative                               | 0.848 (0.841, 0.855)                      | 0.812 (0.797, 0.829)                     | 0.817 (0.802, 0.832)               |

**Abbreviations:** AUC, Area under the receiver operating characteristics curve; CI, confidence interval
eFigure. Model Calibration Curves

Model calibration curves for each model is plotted below for the outcome acute kidney injury in test dataset (n = 8,494).
The final model for the logistic regression with elastic net selection using prehospitalization data (which includes prehospitalization and preoperative data) consisted of 42 variables.

| Variable Group       | Variable Name                        | Type      | Reference          | Odds Ratio (95% CI) | p-value |
|----------------------|--------------------------------------|-----------|--------------------|--------------------|---------|
| Prehospitalization   | Age                                  | Continuous| N/A                | 1.02 (1.01, 1.02)   | <.001   |
|                      | Gender: MALE                         | Binary    | FEMALE             | 1.36 (1.24, 1.49)   | <.001   |
|                      | Marital Status: OTHER/UNKNOWN        | Categorical| MARRIED           | 1.06 (0.94, 1.19)   | 0.347   |
|                      | Marital Status: SINGLE               | Categorical| MARRIED           | 1.07 (0.96, 1.2)    | 0.22    |
|                      | Race: BLACK OR AFRICAN AMERICAN      | Categorical| WHITE             | 1.23 (1.1, 1.37)    | <.001   |
|                      | Race: ASIAN                          | Categorical| WHITE             | 0.87 (0.62, 1.2)    | 0.39    |
|                      | Race: OTHER/UNKNOWN                  | Categorical| WHITE             | 1.3 (1.09, 1.55)    | 0.004   |
|                      | Insurance: MEDICAID                  | Categorical| COMMERCIAL        | 1.21 (1.04, 1.41)   | 0.013   |
|                      | Insurance: MEDICARE                  | Categorical| COMMERCIAL        | 1.23 (1.1, 1.38)    | <.001   |
|                      | Insurance: OTHER                     | Categorical| COMMERCIAL        | 4.43 (3.38, 5.8)    | <.001   |
|                      | Elixhauser AIDS HIV                  | Binary    | No                 | 0.5 (0.26, 0.97)    | 0.039   |
|                      | Elixhauser Alcohol abuse             | Binary    | No                 | 1.09 (0.81, 1.46)   | 0.579   |
|                      | Elixhauser Blood loss anemia         | Binary    | No                 | 0.99 (0.7, 1.4)     | 0.963   |
|                      | Elixhauser Cardiac arrhythmias       | Binary    | No                 | 1.06 (0.93, 1.21)   | 0.376   |
|                      | Elixhauser Chronic pulmonary disease | Binary    | No                 | 1.21 (1.06, 1.38)   | 0.006   |
|                      | Elixhauser Coagulopathy              | Binary    | No                 | 1.09 (0.87, 1.37)   | 0.455   |
|                      | Elixhauser Congestive heart failure  | Binary    | No                 | 1.58 (1.31, 1.9)    | <.001   |
|                      | Elixhauser Deficiency anemia         | Binary    | No                 | 1.14 (0.9, 1.46)    | 0.282   |
|                      | Elixhauser Depression                | Binary    | No                 | 0.82 (0.7, 0.96)    | 0.016   |
|                      | Elixhauser Diabetes complicated      | Binary    | No                 | 1.01 (0.84, 1.22)   | 0.924   |
|                      | Elixhauser Diabetes uncomplicated    | Binary    | No                 | 1.04 (0.9, 1.2)     | 0.619   |
|                      | Elixhauser Drug abuse                | Binary    | No                 | 0.81 (0.61, 1.07)   | 0.142   |
|                      | Elixhauser Fluid and electrolyte disorders | Binary    | No                | 1.36 (1.18, 1.58)   | <.001   |
|                      | Elixhauser Hypertension complicated  | Binary    | No                 | 0.91 (0.73, 1.13)   | 0.399   |
|                      | Elixhauser Hypertension uncomplicated| Binary    | No                 | 1.02 (0.92, 1.13)   | 0.760   |
|                      | Elixhauser Hypothyroidism            | Binary    | No                 | 0.94 (0.8, 1.11)    | 0.465   |
|                      | Elixhauser Liver disease             | Binary    | No                 | 2.19 (1.83, 2.63)   | <.001   |
|                      | Elixhauser Lymphoma                  | Binary    | No                 | 1.19 (0.84, 1.7)    | 0.321   |
|                      | Elixhauser Metastatic cancer         | Binary    | No                 | 0.87 (0.71, 1.07)   | 0.191   |
|                      | Elixhauser Obesity                   | Binary    | No                 | 0.99 (0.87, 1.12)   | 0.828   |
|                      | Elixhauser Other neurological disorders | Binary    | No                | 0.75 (0.6, 0.94)    | 0.011   |
|                      | Elixhauser Paralysis                 | Binary    | No                 | 0.93 (0.59, 1.44)   | 0.735   |
|                      | Elixhauser Peptic ulcer disease      | Binary    | No                 | 0.87 (0.56, 1.36)   | 0.542   |
|                      | Elixhauser Peripheral vascular disease| Binary    | No               | 1.01 (0.87, 1.19)   | 0.856   |
|                      | Elixhauser Psychoses                 | Binary    | No                 | 1.01 (0.58, 1.74)   | 0.982   |
|                      | Elixhauser Pulmonary circulation     | Binary    | No                 | 1.28 (1.02, 1.59)   | 0.031   |
|                      | Elixhauser Renal failure             | Binary    | No                 | 2.59 (2.14, 3.14)   | <.001   |
|                      | Elixhauser Rheumatoid arthritis      | Binary    | No                 | 0.93 (0.74, 1.18)   | 0.552   |
|                      | Elixhauser Solid tumor without metastasis | Binary    | No            | 1.43 (1.28, 1.6)    | <.001   |
|                      | Elixhauser Valvular disease          | Binary    | No                 | 0.98 (0.82, 1.17)   | 0.82    |
|                      | Elixhauser Weight loss               | Binary    | No                 | 1.21 (1, 1.47)      | 0.049   |
|                      | missing Hxdiagnosis                  | Binary    | No                 | 1 (0.54, 1.84)      | 0.995   |
cTable 5. Logistic Regression with Elastic Net Selection Estimates using Preoperative Data

The final model for the logistic regression with elastic net selection using preoperative data (which includes prehospitalization and preoperative data) consisted of 14 variables.

| Variable Group                  | Variable Name                              | Type         | Reference | Odds Ratio (95% CI) | p-value |
|---------------------------------|--------------------------------------------|--------------|-----------|---------------------|---------|
| Interception                   | N/A                                        | N/A          | 0.21(0.11, 0.38) | <.001               |
| Prehospitalization Age         | Continuous                                 | N/A          | 1.01(1.01, 1.01) | <.001               |
| Elixhauser Congestive Heart_Failure | Binary                                   | No           | 1.45(1.22, 1.72) | <.001               |
| Elixhauser Liver_disease       | Binary                                     | No           | 1.51(1.24, 1.83) | <.001               |
| Elixhauser Renal failure       | Binary                                     | No           | 1.67(1.41, 1.97) | <.001               |
| Preoperative                   | GFR Non African_American                   | Continuous   | 0.97(0.97, 0.98) | <.001               |
| Blood_Urea_Nitrogen            | Continuous                                 | N/A          | 1.01(1.01, 1.02) | <.001               |
| Hemoglobin                     | Continuous                                 | N/A          | 0.88(0.86, 0.91) | <.001               |
| International_Normal_Ratio    | Continuous                                 | N/A          | 1.44(1.19, 1.74) | <.001               |
| CCS Nephrectomy partial or complete | Binary                                   | No           | 18.42(14.15, 23.98) | <.001              |
| CCS Other OR therapeutic procedures of urinary tract | Binary                                   | No           | 3.3(2.36, 4.62) | <.001               |
| CCS Other organ_transplantation | Binary                                     | No           | 5.11(3.68, 7.09) | <.001               |
| High Risk Surgery              | Binary                                     | No           | 1.81(1.63, 2) | <.001               |
| missing_Bilirubin_Indirect     | Binary                                     | No           | 0.8(0.71, 0.9) | 0.003               |
| ASA Physical Status            | Continuous                                 | N/A          | 1.54(1.42, 1.67) | <.001               |
eTable 6. Logistic Regression with Elastic Net Selection Estimates using Perioperative Data

The final model for the logistic regression with elastic net selection using perioperative data (which includes prehospitalization, preoperative, and intraoperative data) consisted of 22 variables.

| Variable Group            | Variable Name                        | Type               | Reference | Odds Ratio (95% CI) | p-value |
|---------------------------|--------------------------------------|--------------------|-----------|--------------------|---------|
| Intercept                 | N/A                                  | N/A                | 0.11(0.06, 0.2) | <.001              |
| Prehospitalization        | Age                                  | Continuous         | N/A       | 1.01(1.01, 1.02)   | <.001   |
|                           | Insurance: MEDICAID                  | Categorical        | COMMERCIAL| 1.35(1.16, 1.57)   | <.001   |
|                           | Insurance: MEDICARE                  | Categorical        | COMMERCIAL| 1.14(1.01, 1.28)   | 0.036   |
|                           | Insurance: OTHER                     | Categorical        | COMMERCIAL| 2.2(1.65, 2.91)    | <.001   |
|                           | Elixahauser Congestive Heart Failure | Binary             | No        | 1.49(1.25, 1.77)   | <.001   |
|                           | Elixahauser Liver disease            | Binary             | No        | 1.47(1.2, 1.79)    | <.001   |
|                           | Elixahauser Renal failure            | Binary             | No        | 1.76(1.48, 2.08)   | <.001   |
| Preoperative              | GFR Non African American             | Continuous         | N/A       | 0.97(0.97, 0.98)   | <.001   |
|                           | Blood Urea Nitrogen                  | Continuous         | N/A       | 1.01(1.01, 1.02)   | <.001   |
|                           | Hemoglobin                           | Continuous         | N/A       | 0.89(0.87, 0.92)   | <.001   |
|                           | International Normal Ratio           | Continuous         | N/A       | 1.41(1.17, 1.71)   | <.001   |
|                           | CCS_Nephrectomy partial or complete  | Binary             | No        | 13.11(10.09, 17.04)| <.001   |
|                           | CCS_Other organ transplantation      | Binary             | No        | 3.66(2.5, 5.35)    | <.001   |
|                           | High Risk Surgery                    | Binary             | No        | 1.58(1.42, 1.76)   | <.001   |
|                           | missing Bilirubin Indirect           | Binary             | No        | 0.82(0.72, 0.93)   | 0.002   |
|                           | ASA Physical Status                  | Continuous         | N/A       | 1.49(1.37, 1.62)   | <.001   |
| Intraoperative            | Time to surgery min                  | Continuous         | N/A       | 1(1, 1)            | 0.002   |
|                           | max Estimated Blood Loss mL          | Continuous         | N/A       | 1(1, 1)            | <.001   |
|                           | max Crystalloids mL                  | Continuous         | N/A       | 1(1, 1)            | <.001   |
|                           | Fresh Frozen Plasma YN               | Binary             | No        | 0.97(0.71, 1.32)   | 0.835   |
|                           | Platlets YN                          | Binary             | No        | 1.06(0.76, 1.48)   | 0.737   |
|                           | CaCl_YN                              | Binary             | No        | 1.62(1.3, 2.03)    | <.001   |
### eTable 7. Feature Importance for Random Forest and Gradient Boosting Machine Models

Below are the top 10 features ranked by Gini importance for the random forest and gradient boosting machine models.

| Model (# of variables) | Top 10 Gini Importance Features | Variable Group | Gini coefficient |
|------------------------|---------------------------------|----------------|-----------------|
| Random forest - Prehospitalization (35 variables) | Age | Prehospitalization | 0.176 |
| | Elixhauser Renal failure | Prehospitalization | 0.110 |
| | Insurance commercial | Prehospitalization | 0.067 |
| | Elixhauser Liver disease | Prehospitalization | 0.060 |
| | Insurance medicare | Prehospitalization | 0.049 |
| | Elixhauser Congestive Heart Failure | Prehospitalization | 0.048 |
| | Elixhauser Solid tumor without metastasis | Prehospitalization | 0.045 |
| | Elixhauser Fluid and electrolyte disorders | Prehospitalization | 0.043 |
| | Elixhauser Hypertension complicated | Prehospitalization | 0.040 |
| | Insurance other | Prehospitalization | 0.039 |
| Random forest - Preoperative (309 variables) | Creatinine Level | Preoperative | 0.087 |
| | ASA Physical Status | Preoperative | 0.083 |
| | GFR Non African American | Preoperative | 0.068 |
| | CCS Nephrectomy partial or complete | Preoperative | 0.060 |
| | Age | Prehospitalization | 0.060 |
| | Hemoglobin | Preoperative | 0.054 |
| | Red Blood Cell | Preoperative | 0.045 |
| | Blood Urea Nitrogen | Preoperative | 0.038 |
| | White Blood Cell | Preoperative | 0.035 |
| | Glucose Level | Preoperative | 0.033 |
| Random forest - Perioperative (339 variables) | ASA Physical Status | Preoperative | 0.067 |
| | Creatinine Level | Preoperative | 0.067 |
| | GFR Non African American | Preoperative | 0.057 |
| | CCS Nephrectomy partial or complete | Preoperative | 0.046 |
| | Hemoglobin | Preoperative | 0.037 |
| | Age | Prehospitalization | 0.035 |
| | max Crystalloids mL | Intraoperative | 0.032 |
| | Red Blood Cell | Preoperative | 0.025 |
| | max Estimated Blood Loss mL | Intraoperative | 0.025 |
| | Surgery duration min | Intraoperative | 0.025 |
| Gradient Boosting Machine - Prehospitalization (35 variables) | Age | Prehospitalization | 0.188 |
| | Elixhauser Renal failure | Prehospitalization | 0.091 |
| | Insurance other | Prehospitalization | 0.051 |
| | Elixhauser Liver disease | Prehospitalization | 0.050 |
| | Elixhauser Congestive Heart Failure | Prehospitalization | 0.045 |
| | Elixhauser Solid tumor without metastasis | Prehospitalization | 0.040 |
| | Elixhauser Fluid and electrolyte disorders | Prehospitalization | 0.038 |
| | Sex Female | Prehospitalization | 0.030 |
| | Insurance commercial | Prehospitalization | 0.028 |
| | Elixhauser Chronic pulmonary disease | Prehospitalization | 0.027 |
| Gradient Boosting Machine - Preoperative (309 variables) | CCS Nephrectomy partial or complete | Preoperative | 0.046 |
| | Creatinine Level | Preoperative | 0.083 |
| | Age | Prehospitalization | 0.044 |
| | Prothrombin Time | Preoperative | 0.037 |
| | Hemoglobin | Preoperative | 0.036 |
| | Chloride Level | Preoperative | 0.034 |
| | Red Blood Cell | Preoperative | 0.031 |
| | Glucose Level | Preoperative | 0.029 |
| | White Blood Cell | Preoperative | 0.029 |
| | Sodium Level | Preoperative | 0.029 |
| Gradient Boosting Machine - Perioperative (339 variables) | Creatinine Level | Preoperative | 0.075 |
| Perioperative (339 variables) | CCS 104 | Preoperative | 0.038 |
| max Estimated Blood Loss mL | Intraoperative | 0.033 |
| Age | Prehospitalization | 0.032 |
| Surgery duration min | Intraoperative | 0.026 |
| Max Urine Output | Intraoperative | 0.023 |
| mean Systolic Blood Pressure | Intraoperative | 0.021 |
| mean Diastolic Blood Pressure | Intraoperative | 0.021 |
| Hemoglobin | Preoperative | 0.020 |
| White Blood Cell | Preoperative | 0.020 |
eTable 8. Super Learner Model Performance for Acute Kidney Injury

There were no meaningful differences in model performance when using an ensembling model technique like Super Learner2 (eTable 3 vs. eTable 8).

| Variables       | Algorithm                        | Super Learner Model Weight | Derivation Set, AUC (95% CI) | Validation Set, AUC (95% CI) | Test Set, AUC (95% CI) |
|-----------------|----------------------------------|-----------------------------|------------------------------|-----------------------------|------------------------|
| Prehospitalization | Super Learner Ensemble |                             | 0.675 (0.663, 0.686)         | 0.647 (0.628, 0.667)         | 0.651 (0.632, 0.671)   |
|                  | Random Forest                    | 0.040                       | 0.695 (0.684, 0.707)         | 0.567 (0.546, 0.587)         | 0.603 (0.583, 0.622)   |
|                  | XGBoost                           | 0.134                       | 0.713 (0.702, 0.722)         | 0.619 (0.600, 0.638)         | 0.644 (0.626, 0.664)   |
|                  | Penalized Logistic Regression    | 0.574                       | 0.647 (0.635, 0.658)         | 0.647 (0.628, 0.666)         | 0.646 (0.628, 0.664)   |
|                  | Gradient Boosting Machine        | 0.252                       | 0.658 (0.647, 0.668)         | 0.643 (0.622, 0.662)         | 0.639 (0.619, 0.658)   |
|                  |                                   |                             |                              |                             |                        |
| Preoperative     | Super Learner Ensemble           |                             | 0.988 (0.987, 0.989)         | 0.803 (0.785, 0.818)         | 0.805 (0.789, 0.820)   |
|                  | Random Forest                    | 0.318                       | 1.000 (1.000, 1.000)         | 0.783 (0.765, 0.800)         | 0.792 (0.776, 0.808)   |
|                  | XGBoost                           | 0.154                       | 0.971 (0.968, 0.974)         | 0.779 (0.763, 0.796)         | 0.780 (0.763, 0.797)   |
|                  | Penalized Logistic Regression    | 0.526                       | 0.787 (0.777, 0.797)         | 0.797 (0.781, 0.813)         | 0.793 (0.777, 0.809)   |
|                  | Gradient Boosting Machine        | 0.002                       | 0.781 (0.772, 0.790)         | 0.785 (0.767, 0.802)         | 0.788 (0.772, 0.805)   |
| Perioperative    | Super Learner Ensemble           |                             | 0.988 (0.987, 0.989)         | 0.816 (0.801, 0.830)         | 0.822 (0.806, 0.838)   |
|                  | Random Forest                    | 0.249                       | 1.000 (1.000, 1.000)         | 0.803 (0.788, 0.819)         | 0.812 (0.797, 0.827)   |
|                  | XGBoost                           | 0.208                       | 0.984 (0.982, 0.986)         | 0.786 (0.770, 0.803)         | 0.796 (0.779, 0.811)   |
|                  | Penalized Logistic Regression    | 0.401                       | 0.805 (0.797, 0.814)         | 0.812 (0.796, 0.827)         | 0.810 (0.794, 0.825)   |
|                  | Gradient Boosting Machine        | 0.142                       | 0.802 (0.792, 0.811)         | 0.801 (0.785, 0.817)         | 0.806 (0.791, 0.822)   |
**eTable 9. Model Performance for Acute Kidney Injury When Setting Extreme Covariate Values to Missing**

There were no meaningful differences in model performance when setting variable outlier data to missing (eTable 3 vs. eTable 9).

| Models                                      | Derivation Set (n = 25,616), AUC (95% CI) | Validation Set (n = 8,505), AUC (95% CI) | Test Set (n = 8,494), AUC (95% CI) |
|---------------------------------------------|-------------------------------------------|------------------------------------------|-------------------------------------|
| Logistic Regression with Elastic Net Selection | Prehospitalization 0.695 (0.685, 0.706) | 0.706 (0.687, 0.725) | 0.700 (0.681, 0.719) |
|                                             | Preoperative 0.765 (0.756, 0.775)         | 0.779 (0.762, 0.796) | 0.782 (0.765, 0.799) |
|                                             | Perioperative 0.769 (0.759, 0.779)       | 0.775 (0.758, 0.792) | 0.783 (0.766, 0.800) |
| Random Forest                               | Prehospitalization 0.740 (0.730, 0.750) | 0.712 (0.693, 0.730) | 0.710 (0.692, 0.728) |
|                                             | Preoperative 0.924 (0.920, 0.928)        | 0.788 (0.771, 0.805) | 0.787 (0.770, 0.803) |
|                                             | Perioperative 0.966 (0.964, 0.968)       | 0.799 (0.783, 0.815) | 0.799 (0.782, 0.814) |
| Gradient Boosting Machine                   | Prehospitalization 0.725 (0.714, 0.735) | 0.713 (0.694, 0.731) | 0.712 (0.693, 0.731) |
|                                             | Preoperative 0.819 (0.809, 0.827)        | 0.799 (0.783, 0.814) | 0.803 (0.788, 0.819) |
|                                             | Perioperative 0.862 (0.854, 0.869)       | 0.808 (0.792, 0.824) | 0.815 (0.801, 0.830) |
In response to a reviewer comment, we examined specialty-specific models (top 3 highest volume) and did find some variability, though lower sample sizes seemed like the most important reason for variation in model performance.

| Models                                      | All Encounters (n = 8,494) | Orthopedic Surgery (n = 3,110) | General Surgery (n = 1,758) | Neurological Surgery (n = 1,267) |
|---------------------------------------------|----------------------------|--------------------------------|----------------------------|----------------------------------|
| **Logistic Regression with Elastic Net Selection** | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) |
| Prehospitalization                         | 0.099 | 0.700 (0.681, 0.719) | 0.072 | 0.732 (0.697, 0.767) | 0.108 | 0.660 (0.620, 0.700) | 0.052 | 0.585 (0.514, 0.656) |
| Preoperative                               | 0.782 (0.765, 0.799) | 0.767 (0.733, 0.801) | 0.747 (0.711, 0.783) | 0.710 (0.642, 0.779) |
| Perioperative                              | 0.790 (0.773, 0.807) | 0.767 (0.734, 0.800) | 0.773 (0.739, 0.807) | 0.692 (0.621, 0.763) |
| **Random Forest**                          | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) |
| Prehospitalization                         | 0.099 | 0.710 (0.691, 0.728) | 0.072 | 0.739 (0.702, 0.771) | 0.108 | 0.657 (0.617, 0.697) | 0.052 | 0.625 (0.562, 0.692) |
| Preoperative                               | 0.787 (0.769, 0.803) | 0.782 (0.750, 0.812) | 0.739 (0.706, 0.773) | 0.702 (0.630, 0.771) |
| Perioperative                              | 0.808 (0.792, 0.824) | 0.796 (0.754, 0.816) | 0.772 (0.737, 0.804) | 0.699 (0.626, 0.765) |
| **Gradient Boosting Machine Models**       | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) | AKI Rate | AUC, (95% CI) |
| Prehospitalization                         | 0.099 | 0.712 (0.695, 0.731) | 0.072 | 0.741 (0.706, 0.777) | 0.108 | 0.626 (0.617, 0.698) | 0.052 | 0.624 (0.550, 0.692) |
| Preoperative                               | 0.804 (0.788, 0.819) | 0.786 (0.755, 0.815) | 0.745 (0.709, 0.777) | 0.685 (0.610, 0.753) |
| Perioperative                              | 0.817 (0.802, 0.832) | 0.786 (0.754, 0.816) | 0.775 (0.741, 0.808) | 0.722 (0.659, 0.780) |

**Abbreviations:** AKI, acute kidney injury; AUC, area under the receiver operating characteristic curve; CI, confidence interval
When replicating models for the RIFLE and AKIN AKI definitions, the improvement in model performance across variable groups was similar to performance using the KDIGO definition. The table below shows model performance within the test data set (n = 8,494).

| Acute Kidney Injury Definition and Datasets | Logistic Regression (n = 8,494) | Random Forest (n = 8,494) | Gradient Boosting Machine (n = 8,494) |
|--------------------------------------------|--------------------------------|--------------------------|--------------------------------------|
| **KDIGO Acute Kidney Injury**              |                                |                          |                                      |
| Prehospitalization variables               | AUC (95% CI)                  | p-value for AUC comparison | AUC (95% CI)                  |
|                                           | 0.700 (0.681, 0.719)          | 0.710 (0.690, 0.728)     | 0.712 (0.694, 0.731)              |
|                                           | <.001a                        | <0.001a                   | <0.001a                       |
| Preoperative variables                     | 0.782 (0.765, 0.799)          | 0.787 (0.770, 0.803)     | 0.804 (0.788, 0.819)            |
|                                           | 0.023b                        | <0.001b                   | <0.001b                       |
| Perioperative variables                    | 0.790 (0.773, 0.807)          | 0.808 (0.790, 0.823)     | 0.817 (0.802, 0.832)            |
| **RIFLE Acute Kidney Injury**              |                                |                          |                                      |
| Prehospitalization variables               | 0.669 (0.649, 0.688)          | 0.675 (0.656, 0.693)     | 0.676 (0.657, 0.692)            |
|                                           | <.001a                        | <0.001a                   | 0.001a                       |
| Preoperative variables                     | 0.748 (0.73, 0.766)           | 0.757 (0.740, 0.775)     | 0.776 (0.758, 0.791)            |
|                                           | 0.014b                        | <0.001b                   | 0.001b                       |
| Perioperative variables                    | 0.757 (0.739, 0.775)          | 0.775 (0.759, 0.791)     | 0.792 (0.776, 0.808)            |
| **AKIN Acute Kidney Injury**               |                                |                          |                                      |
| Prehospitalization variables               | 0.698 (0.679, 0.717)          | 0.707 (0.688, 0.725)     | 0.711 (0.692, 0.730)            |
|                                           | <.001a                        | <0.001a                   | <0.001a                       |
| Preoperative variables                     | 0.782 (0.765, 0.799)          | 0.788 (0.772, 0.805)     | 0.802 (0.786, 0.817)            |
|                                           | 0.026b                        | <0.001b                   | <0.001b                       |
| Perioperative variables                    | 0.791 (0.774, 0.808)          | 0.808 (0.793, 0.823)     | 0.819 (0.804, 0.834)            |

**Abbreviations:** AUC, area under the receiver operating characteristic curve; CI, confidence interval; KDIGO, Kidney Disease: Improve Global Outcomes; RIFLE, Risk, Injury, Failure, Loss of kidney function, End stage kidney disease; AKIN, Acute Kidney Injury Network.

* AUC comparison between prehospitalization and preoperative variables; †AUC comparison between preoperative and perioperative variables

Area under the receiver operating characteristic curves (AUC) for each model and acute kidney injury definition are shown for the test set. The AUC, or C-statistic, is calculated along with 95% confidence intervals. DeLong’s test is used to test for significant difference between model AUCs after adding additional clinical variables (p <0.001).
Because the top 20% was an arbitrary cutoff, we also conducted sensitivity analyses of risk stratification using alternate definitions of High Risk at top 10% and top 30%.

| Gradient Boosting Machine | Sample (n = 8,494) | Acute Kidney Injury, No. (%) | In-patient Dialysis, No. (%) | Postoperative Length of Stay ≥7 days, No. (%) | In-Hospital Death, No. (%) |
|---------------------------|-------------------|-----------------------------|-------------------------------|---------------------------------------------|--------------------------|
| Acute Kidney Injury Model Risk Stratification | | | | | |
| Prehospitalization variables | | | | | |
| High Risk | 850 | 247 (29.06) | 17 (2) | 297 (34.94) | 19 (2.24) |
| Low Risk | 7,644 | 598 (7.82) | 15 (0.2) | 1,372 (17.95) | 39 (0.51) |
| Preoperative variables | | | | | |
| High Risk | 850 | 347 (40.82) | 26 (3.06) | 421 (49.53) | 29 (3.41) |
| Low Risk | 7,644 | 498 (6.51) | 6 (0.08) | 1,248 (16.33) | 29 (0.38) |
| Perioperative variables | | | | | |
| High Risk | 850 | 355 (41.76) | 28 (3.29) | 448 (52.71) | 34 (4) |
| Low Risk | 7,644 | 490 (6.41) | 4 (0.05) | 1,221 (15.97) | 24 (0.31) |
| Abbreviations: GBM, Gradient Boosting Machines; AKI: acute kidney injury |

Risk stratification of gradient boosting machines models in the test set (n = 8,494) using alternate definitions of High Risk. Incidence rates of primary and secondary clinical outcomes were calculated from sample totals. In-patient dialysis was defined using ICD-CM-9 procedure codes (eMethods).
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