TECHNICAL NOTES
for the Cardiac Surgery Report

September
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Pennsylvania Health Care Cost Containment Council
Report Period: July 1, 2011 through December 31, 2012

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TABLE OF CONTENTS

OVERVIEW

The Technical Notes serve as a technical supplement to the Pennsylvania Health Care Cost Containment Council's (PHC4) report on coronary artery bypass graft (CABG) and valve surgery for discharges from July 1, 2011 through December 31, 2012. This document describes the methodology and development of the report and includes information on statewide results, cases excluded from the analysis, and risk-adjustment models.

- The analysis included adult patients age 30 or older who underwent a CABG procedure, a valve procedure, or combined valve and CABG procedures in a Pennsylvania general acute care (GAC) hospital. Results are displayed for each of the following procedure groups:
    - CABG without Valve
    - Valve without CABG
    - Valve with CABG
    - Total Valve (combines Valve without CABG and Valve with CABG procedure groups)

- Risk-adjusted measures for hospitals and surgeons with at least 30 cases are reported for:
    - In-hospital mortality
    - 30-day readmissions with a principal diagnosis that indicated a heart-related condition or an infection or a complication

- Average hospital charge (case-mix adjusted) is reported for hospitals with at least 11 cases in a particular procedure group.

- Calendar year 2011 average Medicare payment is reported for hospitals with at least 11 cases in a particular procedure group. If the number of cases included in the payment analysis for either the Valve without CABG or the Valve with CABG procedure group is less than 11, payment data is only reported for the Total Valve procedure group.

- Calendar year 2011 average hospital charge (case-mix adjusted) is reported for the cases in the 2011 average Medicare payment measure. Average charge for procedure groups with fewer than 11 cases is not reported.

The rigorous methodology described in this document was developed to account for the differences among individual patients that had the potential to influence the outcome of CABG and/or valve surgery.

Statewide utilization and outcome data are displayed in Data Table 1.

DATA COLLECTION AND VERIFICATION

The data for the *Cardiac Surgery Report*, obtained from the inpatient UB-04 (Uniform Billing) form, was submitted electronically to PHC4 by Pennsylvania GAC hospitals that performed CABG and/or valve surgery primarily on adults. Federal hospitals were not included. The data included demographic information, hospital charges, and International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes. Hospitals also submitted laboratory test results and supplemental clinical data such as ejection fraction and percent blockage in a coronary artery.

Laboratory test results were submitted by hospitals to the Council for a select group of acute care inpatient records, including those used in the cardiac surgery analysis. Hospitals were required to submit the highest and/or lowest result(s) for a maximum of 29 laboratory tests as collected from patients during the initial period of their hospitalization. The requirements for submitting this data are specified elsewhere (refer to PHC4's *Laboratory Data Reporting Manual,* accessible at www.phc4.org). In brief, for patients admitted prior to 6:00 p.m., only laboratory results collected on Day 1 of the admission were to be submitted. For patients admitted after 6:00 p.m., results were to be submitted for tests collected on the day of admission (Day 1) through the next calendar day (Day 2). Only results of laboratory tests drawn prior to the start date and time of anesthesia for the first CABG and/or valve surgery (and within the laboratory test collection timeframe) were used in the cardiac surgery analysis.

Supplemental clinical data was submitted by hospitals to the Council for inpatient discharges of adult patients in which a CABG and/or valve surgery was performed. Hospitals were required to submit the following clinical data elements related to the first CABG and/or valve surgery of the admission: anesthesia start date and start time, American Society of Anesthesiologists (ASA) class, the ASA emergency indicator, ejection fraction, and percent stenosis in the coronary arteries and their branches. The requirements for submitting this data are specified elsewhere (refer to PHC4's *Cardiac Surgery Supplemental Clinical Data Reporting Manual*, accessible at www.phc4.org).

Facilities submitted data to the Council on a quarterly basis (within 90 days from the last day of each quarter). Upon receipt of the data, verification was performed to assure data were submitted in a readable format. Extensive quality assurance checks were completed and laboratory data and supplemental clinical data submissions were matched to inpatient records. Error reports for UB-04 data were then generated and returned to each facility with an opportunity to correct any problems. Similarly, laboratory test results were evaluated each quarter and summary reports indicating data anomalies were sent to each facility, again with an opportunity to make corrections.

Hospital and Cardiothoracic Surgeon Verification of Data

Hospitals were asked to confirm the accuracy of discharge records, provide additional ICD-9-CM diagnosis and procedure codes as appropriate, and confirm that cases had the correct surgeon assignment. Surgeons were asked to perform a patient level review of the submitted records and then attest to the accuracy of the data and the surgeon assignment. Hospitals and/or surgeons had the opportunity to request special exclusions for cases in which the patient's outcome was most directly associated with conditions unrelated to the CABG/valve surgical episode or the care received during that hospitalization that were not accounted for through risk adjustment. The medical records were reviewed to determine whether special requests for exclusion would be granted. In addition, because of their importance as risk factors, hospitals and surgeons had the opportunity to submit medical records for cases in which cardiogenic shock and/or acute renal failure were present at the time of or immediately prior to the first CABG and/or valve surgery. These records were reviewed to verify that the criteria for preoperative cardiogenic shock and/or preoperative acute renal failure were met. The requirements for submitting cases for medical

record review are specified elsewhere (refer to PHC4's *Guide for Review and Attestation of Cardiac Surgery Data*, accessible at www.phc4.org).

Hospitals were given an opportunity to verify the average Medicare payment reported for their facilities prior to the public release of the information.

STUDY POPULATION

Inclusion Criteria

The study population included records for inpatients discharged from Pennsylvania GAC hospitals between July 1, 2011 and December 31, 2012 who underwent CABG and/or valve surgery as identified by the presence of an applicable ICD-9-CM procedure code(s) in either the principal or secondary procedure code positions of the discharge record.

The population included three subgroups of patients referred to as procedure groups. If a patient underwent multiple CABG/valve surgeries during the same admission, **assignment to one of the three procedure groups was based on the first CABG and/or valve surgery of the admission** as follows:

1. ***CABG without Valve:*** patients who underwent at least one CABG procedure as defined below and no valve procedures on the same day.

ICD-9-CM CABG Procedure Codes	
Code	**Description**
36.10	Aortocoronary bypass for heart revascularization, not otherwise specified
36.11	Aortocoronary bypass of one coronary artery
36.12	Aortocoronary bypass of two coronary arteries
36.13	Aortocoronary bypass of three coronary arteries
36.14	Aortocoronary bypass of four or more coronary arteries
36.15	Single internal mammary-coronary artery bypass
36.16	Double internal mammary-coronary artery bypass
36.17	Abdominal-coronary artery bypass
36.19	Other bypass anastomosis for heart revascularization

2. ***Valve without CABG:*** patients who underwent at least one valve procedure as defined below and no CABG procedures on the same day.

ICD-9-CM Valve Procedure Codes	
Code	**Description**
35.10	Open heart valvuloplasty without replacement, unspecified valve
35.11	Open heart valvuloplasty of aortic valve without replacement
35.12	Open heart valvuloplasty of mitral valve without replacement
35.13	Open heart valvuloplasty of pulmonary valve without replacement
35.14	Open heart valvuloplasty of tricuspid valve without replacement
35.20	Open and other replacement of unspecified heart valve
35.21	Open and other replacement of aortic valve with tissue graft
35.22	Open and other replacement of aortic valve
35.23	Open and other replacement of mitral valve with tissue graft
35.24	Open and other replacement of mitral valve
35.25	Open and other replacement of pulmonary valve with tissue graft
35.26	Open and other replacement of pulmonary valve
35.27	Open and other replacement of tricuspid valve with tissue graft
35.28	Open and other replacement of tricuspid valve
35.33	Annuloplasty
35.99	Other operations on valves of heart

3. ***Valve with CABG:*** patients who underwent at least one of the above valve procedures ***and*** one of the above CABG procedures on the same day.

Results are reported for each of the groups above and for an additional group, Total Valve, which combined results for Valve without CABG and Valve with CABG.

Exclusion Criteria

Cases meeting certain criteria were excluded from the outcome analyses. Standard exclusions were applied to the in-hospital mortality analysis and consisted of the following:

- Patients less than 30 years of age
- Patients who left against medical advice
- Clinically complex cases*

Standard exclusions and exclusions particular to the measure of interest were applied to readmissions and charge analyses.

Additional exclusions for 30-day readmissions included:

- Patients who died during the hospitalization in which the surgery was performed.
- Cases with invalid data (i.e., social security number, date of birth, or sex), which could not be linked to subsequent hospitalizations.
- Out-of-state residents, because these patients could undergo a CABG and/or valve surgery in a Pennsylvania hospital, return to their state of residence and be readmitted to a hospital in their home state. As such, readmission data would not be available for these patients.
- Patients who were discharged in December 2012, because January 2013 data was not available (at the time of analysis) to identify readmissions for these discharges.

Additional exclusions for average hospital charge included:

- Patients with invalid or missing charges, including cases with charges that were less than $10,000.
- Cases in tracheostomy Diagnostic Related Group (MS-DRG) 003 and Major Diagnostic Category (MDC) 5.
- Cases in low volume MS-DRGs, including MS-DRG groups when a particular combination of procedure group/PA region/MS-DRG group had fewer than 10 cases.
- Charge outliers, which were determined using the "+/- 3.0 interquartile range" method (after accounting for differences in charges by procedure group, PA region, and MS-DRG group).

Data Table 2 displays exclusion data for each of these outcome measures.

* Clinically complex cases included cases with one of the ICD-9-CM codes in Appendix A (Tables A1, A2, A3, and A4), cases *not* in the study MS-DRGs (See Appendix A: Table A5 for MS-DRGs included in the study), and cases granted special request for exclusion.

MEASURES REPORTED

Number of Cases

The number of cases (after standard exclusions were removed) is reported for hospitals and surgeons for each procedure group.

Risk-Adjusted In-Hospital Mortality Rating

In-hospital mortality was identified in the patient discharge record as a discharge status of "20." The rating identifies whether the hospital's or surgeon's observed mortality rate was significantly higher than, significantly lower than, or not significantly different than expected based on patient risk factors. This measure is reported for each hospital and surgeon with 30 or more cases in a particular procedure group.

Risk-Adjusted 30-Day Readmissions Rating

A hospital readmission was defined as a rehospitalization to a Pennsylvania GAC hospital within 1 to 30 days of discharge from the hospitalization in which the CABG/valve surgery was performed. A readmission was counted only if the patient was readmitted with a principal diagnosis that indicated a heart-related condition or an infection or complication. (Data Table 3 displays the number of readmissions for each category. Appendix B lists the diagnosis categories and their associated ICD-9-CM codes included in the readmissions analysis.)

A hospitalization that resulted in more than one readmission within 30 days was counted only once even though it resulted in multiple readmissions. If, over the study period, a patient had multiple discharges for CABG/valve surgery, each discharge was independently investigated to determine whether it had a readmission within 30 days of that discharge.

The readmission analysis included discharges from July 1, 2011 through November 30, 2012. December 2012 data was used to identify 30-day readmissions for patients discharged in November 2012.

The rating identifies whether the hospital's or surgeon's observed readmission rate was significantly higher than, significantly lower than, or not significantly different than expected based on patient risk factors. This measure is reported for each hospital and surgeon with 30 or more cases in a particular procedure group.

Case-Mix Adjusted Average Hospital Charge

The amount a hospital bills for a patient's care is known as the charge. The charge includes the facility fee for the entire hospitalization during which the CABG/valve surgery was performed (not just the treatment associated with surgery). It does not include professional fees (e.g., physician fees) or other additional post-discharge costs, such as rehabilitation treatment, long-term care and/or home health care. The average charges reported were trimmed and case-mix adjusted. Average charges are reported for each hospital with 11 or more cases in a particular procedure group.

Calendar Year 2011 Average Medicare Fee-for-Service Payment

The average Medicare payment is for Medicare fee-for-service (FFS) cases only and is for calendar year 2011, since this was the most recent Medicare payment data available. This timeframe differs somewhat from the cases included in the outcome analyses, which does not include discharges from Quarters 1 and 2, 2011 because hospitals did not begin reporting to PHC4 the supplemental clinical data used for risk adjustment until Quarter 3, 2011.

The Medicare payment data for 2011 was provided to PHC4 by the Centers for Medicare and Medicaid Services (CMS) and then matched by PHC4 to the 2011 cardiac surgery cases meeting the study population criteria (after standard exclusions). Only cases where the Medicare payment appeared to be valid ($10,000 or more) were included. The average payment was calculated using the dollar amount that CMS provided for the Medicare Part A hospital insurance fund payment. Patient liabilities (e.g., coinsurance and deductible dollar amounts) were not included. Also not included were payments from Medicare Advantage plans (Medicare HMOs) and any special pass-through payments facilities sometimes receive for unusual capital or other costs.

The average payment was calculated by summing the Medicare FFS payment amounts for the cases in a particular procedure group and dividing the sum by the number of cases in that procedure group.

Average Medicare payment (along with the number of cases included in the average payment) is reported for hospitals only. To meet current CMS privacy guidelines, average payments (and the number of cases included in the average payment) are only displayed for procedure groups with 11 or more cases. If the number of cases included in the payment analysis for either the Valve without CABG or the Valve with CABG procedure group is less than 11, the number of cases and average payment for both of these procedure groups is not reported.

Hospitals were given an opportunity to verify the average Medicare payment reported for their facilities prior to the public release of the information.

Calendar Year 2011 Average Hospital Charge for Medicare Fee-for-Service Cases

Case-mix adjusted average charge is reported for the Medicare cases included in the 2011 average Medicare payment. While the same cases included in the average Medicare payment were included in the charge analysis, the final case-mix adjusted average charge may include fewer cases as a result of exclusions specific to the charge analysis. Average charges are not reported when payment information is not reported for a particular procedure group or when there are fewer than 11 cases in the average charge analysis for a particular procedure group.

RISK-ADJUSTMENT METHODOLOGY

In order to report fair comparisons among hospitals and surgeons, regression techniques were used to construct "risk models" for predicting the risk of mortality or readmission. Each model was a mathematical formula used to ultimately predict a patient's probability of death or readmission based on relevant risk factors. Cases with these risk factors were given more "credit" in the calculation, leading to a higher predicted probability of mortality or readmission. A hospital's or surgeon's predicted rate was the average predicted probability across all its discharges in a particular procedure group. The ratings indicate whether the hospital's or the surgeon's mortality or readmission rates were within the expected range or higher or lower than the expected range, taking into account the risk factors that were included in the risk-adjustment models.

Model Development

For modeling in-hospital mortality, the reference database included CABG/valve discharges from January 1, 2011 through December 31, 2012 (after exclusions). For 30-day readmissions, the reference database included CABG/valve discharges from January 1, 2011 through November 30, 2012 (after exclusions), because January 2013 data was not available (at the time of analysis) to identify readmissions for these discharges. Data Table 1 displays frequencies for the datasets and statewide outcomes.

Identifying potential risk factors. The first step in building the models was to identify potential risk factors, that is, factors that potentially contributed to these events (mortality and readmission). These factors were identified through their importance in past models, review of scientific literature and consideration of high-risk populations. Types of risk factors included procedure group, patient demographics, clinically derived data (i.e., supplemental clinical data, results of medical record reviews for preoperative cardiogenic shock and preoperative acute renal failure, and laboratory test results), and diagnoses and procedures identified by ICD-9-CM codes. Data Tables 4 and 5 display frequency data for the potential risk factors. Definitions for ICD-9-CM code-based variables are available in Appendix C.

Using the reference database, potential risk factors were subject to univariate analysis to determine which, because of their potential to predict the event of interest, should be tested for inclusion in the model. Variables were constructed and analyzed as linear (continuous), categorical, and binary as appropriate. For some factors multiple forms of variable construction were analyzed to determine which approach best fit the data (i.e., provided the highest model likelihood). For example,

- Patient age was tested as a linear, linear spline with up to two knots, or quadratic factor. The linear spline approach yielded the best results for both models.
- Variables representing the percent blockage in a coronary artery were analyzed in all formats—linear, categorical, and binary. Performance of the various variable constructions was compared and the form of the variable with the highest likelihood of predicting the event was selected for testing in the model.

When constructing categorical variables, data was partitioned into a maximum of five categories as appropriate:

- For variables with continuous data (e.g., percent blockage in a coronary artery and laboratory test results) one category represented "typical" results with additional categories representative of abnormal results generally associated with increased risk. (In the final model, all records in a specified abnormal category would receive the same amount of credit, regardless of the value within the category.) Records with missing values were combined with records in the typical category.

- For ICD-9-CM code based categorical variables, one category represented the absence of the risk factor and additional categories represented the presence of diagnosis/procedure codes indicating increased risk for that particular condition (e.g., no diabetes, diabetes with complications, and diabetes without complications).

Categorical and binary variables were selected for testing in the model based on the following criteria:

- Minimum volume: For categorical variables, each category represented at least one percent of the total volume. For binary variables, cases with the risk factor were required to represent at least one percent of the total volume. Exceptions were made to this criterion when a variable had particular clinical relevance to the outcome.
- Order of risk: For categorical variables, categories farther away from the "typical" category were required to have rates of increasing risk (e.g., when the typical category was defined as level A, categories B, C, D, and E were required to have increasingly higher rates of risk). For binary variables, cases with the risk factor were required to have a higher rate of risk than cases without the risk factor.
- Significance: Variables were required to have significance ($p<0.10$). Exceptions were made to this criterion when a variable had particular clinical relevance to the outcome.

Model selection. Using binary logistic regression, risk factors selected for testing were added to the model in the following order: 1) procedure group and patient demographics (gender, race/ethnicity, age), 2) supplemental clinical data, 3) record review results, 4) laboratory test results, then 5) ICD-9-CM code-based variables. All factors within a risk factor type were evaluated before considering factors from the next type.

Risk factors were considered statistically significant in a model if they met the $p<0.10$ significance criterion and indicated an increase in the risk of the event (in-hospital mortality or 30-day readmission). However, risk factors were evaluated for relevance by considering both mathematical (statistical significance) and clinical perspectives (clinically important populations).

Bootstrap validation. Once the model variables were chosen, the model was validated using the bootstrap technique to evaluate the stability of each factor in the prepared model. Using this technique, five hundred sample datasets were randomly generated from the reference database. Records were allowed to appear multiple times in the sample datasets if they were selected repeatedly. The prepared model was then fit to each sample dataset to determine the percent of sample models in which each factor maintained significance ($p<0.10$). Risk factors at or above a 70% cutoff and those with particular clinical relevance to the outcome (even if below the 70% cutoff) were retained in the final model. This same approach was used to eliminate any factor that did not have a consistently positive numeric value/coefficient (reflective of an increased risk) in at least 70% of the sample models. (See the "Coefficients and Odds Ratios" section for a description of model coefficients.)

Measure of Model Adequacy. The c-statistic was used to measure model adequacy. The c-statistic, the measure of "goodness of fit" used to describe a logistic regression model, is a common measure for models with binary dependent variables. For binary outcomes, the c-statistic is defined as the area under the receiver operating characteristic (ROC) curve.* The c-statistic ranges between 0.5 and 1.0, with higher values associated with better discrimination, and can be expressed as a percent ranging from 50% to 100%. In some respects, the c-statistic is similar to the R^2 (Coefficient of Determination) commonly used in linear regression. Both the c-statistic and R^2 approach 1.0 for models that perfectly discriminate. However, unlike R^2, the c-statistic is not dependent on the frequency of the outcome. The c-statistics for the in-hospital mortality and 30-day readmissions models are listed in Data Tables 6 and 7, respectively.

* Hanley, J. A., & McNeil, B. J. (1982). The meaning and use of the area under a receiver operating characteristic (ROC) curve. *Radiology, 143*(1), 29-36.

Coefficients and Odds Ratios. Coefficients are mathematical values derived from the regression analysis that correspond to a given level of risk. They are used in the mathematical formula that calculates a patient's overall predicted risk of the event (mortality or readmission). The odds ratios are used to interpret the impact of the risk factors on the probability of the event. For a binary variable, the odds ratio is the change in the odds for a patient with the risk factor compared to a patient without it. For example, in the in-hospital mortality model, the odds ratio for ASA Class 5 is 2.474, meaning that a patient with ASA Class 5 was more than two times as likely to die during the hospital admission than patients in ASA Class 1, 2, 3, or 4. The coefficients and odds ratios for each risk factor included in the mortality and readmission models are listed in Data Tables 6 and 7, respectively.

Calculating Statistical Ratings

Separate analyses were performed to determine, for each hospital and surgeon, the actual percent of in-hospital mortality and the actual percent of 30-day readmissions with a principal diagnosis that indicated a heart-related condition or complication or infection. For mortality and readmissions, significance tests were conducted to determine whether the difference between a hospital's or surgeon's actual and expected values was too large to be attributed solely to chance. These results were displayed as ratings. Ratings were reported for hospitals and surgeons with 30 or more cases in a particular procedure group.

Determining Actual Values

In-Hospital Mortality Percent	This percent was determined by dividing the total number of hospitalizations in which the patient died by the number of hospitalizations in the mortality analysis for a particular procedure group.
30-Day Readmission Percent	This percent was determined by dividing the number of hospitalizations for which the patient was readmitted at least once (with a principal diagnosis that indicated a heart-related condition or an infection or complication*) to any Pennsylvania GAC hospital within 1 to 30 days of discharge, by the total number of hospitalizations included in the readmissions analysis for a particular procedure group.

Determining Expected Values

The final risk models estimated the relative effects (β_n) that each of the risk factors had on the relevant outcome value for each hospitalization. The model equations took the following form:

$$\beta X = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \ldots \beta_n x_n$$

where:

β_n = the relevant model coefficient (β_0 is the intercept)
x_n = the value of the risk factor for a hospitalization

These models were then used to calculate the predicted values (e.g., predicted probability of death or readmission) for each individual hospitalization (after exclusions). The risk factor values (X) were multiplied by the model coefficients (β) and summed to determine the value βX for each hospitalization.

Using logistic regression modeling, the predicted value was calculated as:

* See Appendix B for definitions.

$$p = \frac{e^{\beta X}}{1 + e^{\beta X}}$$

where $e \approx 2.7182818285$

The expected value for an individual hospital or surgeon was the average of these predicted values for all hospitalizations for particular hospital or surgeon.

Determining Statistical Ratings

Statistical evaluation was used to determine whether the difference between a hospital's or surgeon's observed and expected values was *too large* to be attributed solely to chance. Significance tests (using test statistics and p-values as described below) were performed to account for random variation.

The test statistic was calculated using the following equations:

z = (Actual – Expected) / Standard Deviation

With standard deviation being calculated as follows:

Step 1: Compute the estimated variance of the event for each patient (VARPAT):

VARPAT = (p) (1-p)

Step 2: Calculate the Standard Deviation of Mortality

SUMVAR = sum of VARPAT across all cases

Standard Deviation of Mortality = square root of SUMVAR

A two-tailed p-value was calculated using the test statistic above as a normal z-score.

Assignment of Statistical Ratings

Differences between actual and expected values were considered to be statistically significant when p-values were <0.05. A statistical rating of higher than expected or lower than expected was assigned to each hospital or surgeon if the difference between what was observed and what was expected in a particular procedure group was statistically significant.

- If the p-value was <0.05 and the test statistic was <0, then the conclusion was made that the difference between the expected and actual number of events was statistically significant and fewer than the expected number of events had occurred. The hospital or surgeon was assigned the symbol "○" (as shown in the cardiac surgery report).

- If the p-value was <0.05 and the test statistic was >0, then the conclusion was made that the difference between the expected and actual number of events was statistically significant and more than the expected number of events had occurred. The hospital or surgeon was assigned the symbol "●" (as shown in the cardiac surgery report).

- If the calculated p-value was greater than or equal to 0.05, then the conclusion was made that the difference between the expected and actual number of events was *not* statistically significant. In this case the hospital or surgeon was assigned the symbol "⊙" (as shown in the cardiac surgery report).

See Appendix D for an example of logistic regression and calculation of statistical ratings.

CASE-MIX ADJUSTMENT METHODOLOGY

Charges were adjusted to account for differences in charges across regions of Pennsylvania and hospital variation in the mix of cases across MS-DRGs. Average charges were trimmed for outliers and case-mix adjusted for each of the three procedure groups (CABG without Valve, Valve without CABG, and Valve with CABG) separately. A case-mix adjusted charge is reported for hospitals only, for each procedure group in which the hospital had 11 or more cases in the analysis after all exclusions satisfied.

Construction of Reference Database

After standard exclusions and cases with invalid charges, cases in tracheostomy MS-DRG (003) and MDC 5, and cases in low volume MS-DRGs were removed, the reference database was constructed by assigning each case to the appropriate procedure group/PA region/MS-DRG group combination based on the hospital's geographic location and the MS-DRG assignment for the case. Then cases in procedure group/PA region/MS-DRG group combinations with less than 10 cases were excluded. Then trimming was performed.

Patients who underwent CABG without valve procedures were comprised of the following MS-DRG groups:

MS-DRG Group 1	MS-DRG 231	Coronary Bypass with PTCA with MCC
	MS-DRG 232	Coronary Bypass with PTCA without MCC
MS-DRG Group 2	MS-DRG 233	Coronary Bypass with Cardiac Catheterization with MCC
	MS-DRG 234	Coronary Bypass with Cardiac Catheterization without MCC
MS-DRG Group 3	MS-DRG 228	Other Cardiothoracic Procedures with MCC
	MS-DRG 229	Other Cardiothoracic Procedures with CC
	MS-DRG 230	Other Cardiothoracic Procedures without CC/MCC
MS-DRG Group 4	MS-DRG 235	Coronary Bypass without Cardiac Catheterization with MCC
	MS-DRG 236	Coronary Bypass without Cardiac Catheterization without MCC

Patients who underwent valve procedures with or without CABG procedures were comprised of the following MS-DRG groups:

MS-DRG Group 5	MS-DRG 216	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with MCC
	MS-DRG 217	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with CC
	MS-DRG 218	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization without CC/MCC
MS-DRG Group 6	MS-DRG 219	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization with MCC
	MS-DRG 220	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization with CC
	MS-DRG 221	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization without CC/MCC

Trim Methodology

Trimming was used to remove outlier charges from the study population. Identification of outliers eliminates extreme values that may have a significant and unrepresentative impact on the average.

Since charges varied dramatically among regions, upper and lower trim points were calculated at the regional level for each MS-DRG group within each procedure group. Cases with charges that were below the lower trim point or above the upper trim point were excluded from further analysis.

For this analysis, upper and lower trim points were calculated using the "+/- 3.0 interquartile range" method. This non-parametric methodology was used because, historically, the distribution for charges does not follow a normal "bell-shaped" pattern.

Trim points were determined as follows:

Q1 = *the first quartile (25th percentile total charge) of all patient records from the comparative database in a particular category*

Q3 = *the third quartile (75th percentile total charge) of all patient records from the comparative database in a particular category*

IQR = *Q3 – Q1*

Lower Trim Point = *Q1 – (3.0 x IQR)*

Upper Trim Point = *Q3 + (3.0 x IQR)*

Determining Actual Charges

The actual average charge (Average ActChg) was determined as the average (arithmetic mean) charge for the hospitalizations included in the hospital's charge analysis for a particular procedure group.

Determining Expected Charges

The expected charge (ExpChg) for a hospitalization was equal to the average charge for all hospitalizations in that particular region/MS-DRG group combination for a particular procedure group.

The hospital's expected charge was determined as the average (arithmetic mean) of the expected charges for the hospitalizations included in the hospital's charge analysis for a particular procedure group:

$$\text{Average ExpChg} = \frac{\Sigma\ \text{ExpChg}}{n}$$

Determining Case-Mix Adjusted Charges

The case-mix adjusted charge was calculated by dividing the average actual charges (Average ActChg) by the average expected charge (Average ExpChg) for the hospital, and then multiplying this quantity by the average charge for the hospital's region for the relevant procedure group:

$$\frac{\text{Average ActChg}}{\text{Average ExpChg}}\ \text{(Average Actual Charge for a particular region)}$$

See Appendix E for an example of how case-mix adjusted charges were computed.

DATA TABLES

TABLE 1. STATEWIDE UTILIZATION AND OUTCOME DATA

July 1, 2011 to December 31, 2012 Data

	Cases	In-Hospital Mortality	
	#	#	%
Total cases	**20,164**	**441**	**2.2**
CABG without Valve	11,612	178	1.5
Valve without CABG	5,531	120	2.2
Valve with CABG	3,021	143	4.7
Total Valve	8,552	263	3.1

	Cases	30-Day Readmissions*	
	#	#	%
Total cases	**16,694**	**2,275**	**13.6**
CABG without Valve	9,826	1,174	11.9
Valve without CABG	4,432	663	15.0
Valve with CABG	2,436	438	18.0
Total Valve	6,868	1,101	16.0

	# Cases	Actual Average Charge
Total cases	**19,252**	**$170,734**
CABG without Valve	11,113	$150,927
Valve without CABG	5,290	$185,898
Valve with CABG	2,849	$219,839
Total Valve	8,139	$197,779

January 1, 2011 to December 31, 2011 Data

	# Cases	Actual Average Medicare FFS Payment
Total cases	**4,608**	**$40,336**
CABG without Valve	2,359	$32,574
Valve without CABG	1,380	$47,550
Valve with CABG	869	$49,950
Total Valve	2,249	$48,477

	# Cases	Actual Average Charge for Medicare Cases
Total cases	**4,325**	**$167,794**
CABG without Valve	2,212	$143,647
Valve without CABG	1,301	$184,608
Valve with CABG	812	$206,633
Total Valve	2,113	$193,072

* The readmission analysis included discharges from July 1, 2011 through November 30, 2012. December 2012 data was used to identify 30-day readmissions for patients discharged in November.

DATA TABLES

TABLE 2. EXCLUSION DATA

Table 2A. In-Hospital Mortality Exclusions

	Cases		In-Hospital Mortality	
	#	%	#	%
July 1, 2011 to December 31, 2012 Data				
Total cases prior to in-hospital mortality exclusions	22,919	100.0	642	2.8
Exclusions:				
• *Patients <30 years of age*	*155*	*0.7*	*6*	*3.9*
• *Patients who left against medical advice*	*13*	*0.1*	*0*	*0.0*
• *Clinically complex cases*[1]	*2,587*	*11.3*	*195*	*7.5*
Total exclusions	*2,755*	*12.0*	*201*	*7.3*
Total cases remaining in analysis	**20,164**	**88.0**	**441**	**2.2**

[1] Clinically complex cases included cases with one of the ICD-9-CM codes in Appendix A (Tables A1, A2, A3, and A4), cases *not* in the study MS-DRGs (See Appendix A: Table A5 for MS-DRGs included in the study), and cases granted special request for exclusion.

Table 2B. 30-Day Readmissions Exclusions

	Cases		30-Day Readmissions	
	#	%	#	%
July 1, 2011 to November 30, 2012 Data				
Total cases after in-hospital mortality exclusions	20,164	100.0	–	–
Additional exclusions:				
• *Patients who died during hospitalization in which surgery was performed*	*441*	*2.2*	–	–
• *Cases with invalid data*[1]	*237*	*1.2*	–	–
• *Out-of state residents*[2]	*1,765*	*8.8*	–	–
• *December 2012 Discharges*[3]	*1,027*	*5.1*		
Total exclusions	*3,470*	*17.2*	–	–
Total cases remaining in analysis	**16,694**	**82.8**	**2,275**	**13.6**

[1] Cases with invalid data (i.e., social security number, date of birth, or sex) could not be linked to subsequent hospitalizations.

[2] Out-of-state residents were excluded because such patients could undergo a CABG and/or valve surgery in a Pennsylvania hospital, return to their state of residence and be readmitted to a hospital in their home state. Therefore, readmission data would not be available for these patients.

[3] Patients who were discharged in December 2012 were excluded because January 2013 data was not available (at the time of analysis) to identify readmissions for these discharges.

DATA TABLES

TABLE 2. EXCLUSION DATA *CONTINUED*

Table 2C. Average Charge Exclusions

	Cases		Average Charge
	#	%	
July 1, 2011 to December 31, 2012 Data			
Total cases after in-hospital mortality exclusions	20,164	100.0	$190,346
Additional exclusions:			
• *Patients with invalid or missing charges*[1]	*0*	–	–
• *Cases in tracheostomy MS-DRG*[2]	*422*	*2.1*	*$620,985*
• *Cases in low volume MS-DRGs*[3]	*184*	*0.9*	*$480,162*
• *Cases that were charge outliers*[4]	*306*	*1.5*	*$656,066*
Total exclusions	*912*	*4.5*	–
Total cases remaining in analysis	**19,252**	**95.5**	**$170,734**
Average Charge Analysis for 2011 Average Medicare Payment Cases			
Total cases after in-hospital mortality exclusions	4,608	100.0	$189,701
Additional exclusions:			
• *Patients with invalid or missing charges*[1]	*1*	*<0.1*	*$237*
• *Cases in tracheostomy MS-DRG*[2]	*110*	*2.4*	*$613,588*
• *Cases in low volume MS-DRGs*[3]	*80*	*1.7*	*$290,691*
• *Cases that were charge outliers*[4]	*92*	*2.0*	*$626,977*
Total exclusions	*283*	*6.1*	–
Total cases remaining in analysis	**4,325**	**93.9%**	**$167,794**

[1] Invalid/missing charges included cases with charges that were less than $10,000.

[2] Tracheostomy cases were assigned to MS-DRG 003 and MDC 5.

[3] MS-DRGs with low volume, including MS-DRG groups when a particular combination of procedure group/PA region/MS-DRG group had fewer than 10 cases.

[4] Charge outliers were determined using the "+/- 3.0 interquartile range" method—after accounting for differences in charges by procedure group, PA region, and MS-DRG group.

DATA TABLES

TABLE 3. 30-DAY READMISSIONS DATA

N = 2,275

	#	%
CIRCULATORY SYSTEM	**1,045**	**45.9**
Cardiac Dysrhythmias	270	11.9
Heart Block	6	0.3
Paroxysmal Tachycardia	15	0.7
Atrial Fibrillation and Atrial Flutter	214	9.4
Ventricular Fibrillation and Ventricular Flutter	6	0.3
Premature Heart Beats	2	0.1
Other Cardiac Dysrhythmias	27	1.2
Heart Failure	361	15.9
Functional Disturbances Follow Cardiac Surgery (Postcardiotomy Syndrome)	66	2.9
Hypertension and Hypotension	43	1.9
Hypertension	3	0.1
Hypotension	40	1.8
Myocardial Infarction and Ischemia	48	2.1
Acute Myocardial Infarction, Initial Episode	42	1.8
Acute Myocardial Infarction, Unspecified or Subsequent Episode	0	0.0
Other Forms of Myocardial Ischemia	6	0.3
Angina Pectoris and Chest Pain	53	2.3
Atherosclerosis	37	1.6
Coronary Atherosclerosis	24	1.1
Other Atherosclerosis	13	0.6
Heart Aneurysm and Dissection	0	0.0
Endocarditis, Myocarditis, and Pericarditis	56	2.5
Heart Valve Disease	1	<0.1
Mitral Valve Disease	0	0.0
Aortic Valve Disease	1	<0.1
Tricuspid Valve Disease	0	0.0
Pulmonary Valve Disease	0	0.0
Multiple Valve Disease	0	0.0
Other Endocardial Structure Disease	0	0.0
Cardiomyopathies	0	0.0
Other Aneurysm and Dissection	4	0.2
Aortic Aneurysm and Dissection	3	0.1
Other Arterial Aneurysm	1	<0.1
Other Arterial Dissection	0	0.0
Arterial Embolism and Thrombosis	4	0.2
Abdominal and Thoracic Aorta	0	0.0

DATA TABLES

TABLE 3. 30-DAY READMISSIONS DATA

N = 2,275

	#	%
Arteries of the Extremities	4	0.2
Other Arteries Excluding Precerebral and Cerebral Arteries	0	0.0
Venous Embolism and Thrombosis	22	1.0
Lower Extremity Venous Embolism and Thrombosis	16	0.7
Renal Vein Embolism and Thrombosis	0	0.0
Other Venous Embolism and Thrombosis	6	0.3
Phlebitis and Thrombophlebitis	1	<0.1
Lower Extremity Phlebitis and Thrombophlebitis	1	<0.1
Upper Extremity Phlebitis and Thrombophlebitis	0	0.0
Other Vessel Phlebitis and Thrombophlebitis	0	0.0
Occlusion and Stenosis	7	0.3
Precerebral Artery Occlusion and Stenosis	2	0.1
Cerebral Artery Occlusion and Stenosis	5	0.2
Retinal Artery Occlusion and Visual Loss	0	0.0
Stroke	64	2.8
Ischemic Stroke	42	1.8
Hemorrhagic Stroke	5	0.2
Transient Cerebral Ischemia	14	0.6
Postoperative Stroke	3	0.1
Other Diseases and Symptoms of the Circulatory System	8	0.4
RESPIRATORY SYSTEM	**285**	**12.5**
Pulmonary Embolism and Infarction	73	3.2
Pulmonary Embolism and Infarction	53	2.3
Postoperative Pulmonary Embolism and Infarction	20	0.9
Pleural Effusion and Atelectasis	130	5.7
Pneumothorax	7	0.3
Pneumothorax	6	0.3
Postoperative Pneumothorax	1	<0.1
Pulmonary Edema	2	0.1
Acute Respiratory Failure	53	2.3
Other Diseases and Symptoms of the Respiratory System	20	0.9
NERVOUS SYSTEM	**65**	**2.9**
Encephalopathies	5	0.2
Cerebral Edema and Brain Compression	0	0.0
Anoxic Brain Damage	0	0.0
Coma and Stupor	2	0.1

DATA TABLES

TABLE 3. 30-DAY READMISSIONS DATA

N = 2,275

	#	%
Postoperative Pain	14	0.6
Other Diseases and Symptoms of the Nervous System	44	1.9
DIGESTIVE SYSTEM	**90**	**4.0**
Ischemic Bowel and Vascular Insufficiency of the Intestine	5	0.2
Intestinal Obstruction and Ileus	8	0.4
Ulceration, Bleeding and Perforation of the Digestive System	63	2.8
Acute Liver Failure	1	<0.1
Other Diseases and Symptoms of the Digestive System	13	0.6
URINARY SYSTEM	**51**	**2.2**
Acute Glomerulonephritis and Pyelonephritis	0	0.0
Nephrotic Syndrome	0	0.0
Acute Renal Failure	48	2.1
Other Diseases and Symptoms of the Urinary System	3	0.1
COMPLICATIONS OF SURGICAL AND MEDICAL CARE	**248**	**10.9**
Mechanical Complication of Cardiac Device, Implant and Graft	7	0.3
Mechanical Complication of Cardiac Pacemaker and AICD	0	0.0
Mechanical Complication of Heart Valve Prosthesis	3	0.1
Mechanical Complication of Coronary Artery Bypass Graft	3	0.1
Other and Unspecified Mechanical Complication	1	<0.1
Other Complication of Internal Prosthetic Device, Implant and Graft	19	0.8
Other Complication of Heart Valve Prosthesis	2	0.1
Other Complication of Other Cardiac Device, Implant and Graft	13	0.6
Other Complicaton of Vascular Device, Implant and Graft	4	0.2
Shock	0	0.0
Postoperative Shock	0	0.0
Cardiogenic Shock	0	0.0
Other Shock	0	0.0
Hemorrhage and Hematoma Complicating a Procedure	26	1.1
Foreign Body Accidentally Left or Accidental Laceration During a Procedure	2	0.1
Dehiscence and Rupture of Operation Wound	40	1.8
Other Complications of Surgical and Medical Care	154	6.8
Nervous System Complication	0	0.0
Circulatory System Complication	97	4.3
Respiratory System Complication	51	2.2
Digestive System Complication	1	<0.1
Urinary System Complication	1	<0.1

DATA TABLES

TABLE 3. 30-DAY READMISSIONS DATA

N = 2,275

	#	%
Other Complications	4	0.2
INFECTIONS	**418**	**18.4**
Postoperative Infections	157	6.9
Sepsis and Bacteremia	85	3.7
Pneumonia	87	3.8
Pneumonia	72	3.2
Aspiration Pneumonia	15	0.7
Empyema and Abscess of Lung	2	0.1
Infection due to Device, Implant and Graft	15	0.7
Cardiac Device, Implant and Graft	6	0.3
Vascular Device, Implant and Graft	5	0.2
Other and Unspecified Infections due to Device, Implant and Graft	4	0.2
Urinary Tract Infection	26	1.1
Cellulitis	20	0.9
Osteomyelitis	0	0.0
Intestinal Infection due to Clostridium difficile	15	0.7
Other Infection Related Conditions and Symptoms	11	0.5
FLUID AND ELECTROLYTE IMBALANCE	**26**	**1.1**
Hyperosmolality and Hyposmolality	3	0.1
Acidosis and Alkalosis	0	0.0
Dehydration and Hypovolemia	18	0.8
Fluid Overload	4	0.2
Hyperpotassemia and Hypopotassemia	1	<0.1
Other Electrolyte and Fluid Disorders	0	0.0
ANEMIA AND COAGULATION DEFECTS	**47**	**2.1**
Anemia	28	1.2
Acute Posthemorrhagic Anemia	14	0.6
Anemia	14	0.6
Coagulation Defects	19	0.8
Hemorrhagic Disorders due to Anticoagulants	0	0.0
Thrombocytopenia	11	0.5
Other Coagulation Defects	8	0.4

DATA TABLES

TABLE 4. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – IN-HOSPITAL MORTALITY

Candidate Variable	Cases N = 20,164		In-Hospital Mortality 2.2%	
	Number	Percent	Number	Percent
Variables tested and retained in the model.				
Procedure Group Factor				
CABG without Valve	11,612	57.6%	178	1.5%
Valve without CABG	5,531	27.4%	120	2.2%
Valve with CABG	3,021	15.0%	143	4.7%
Demographic Factors				
Age (continuous)	20,164	Average Age – 67.5 (Female 69.5, Male 66.4)		
Age – Number of Years >60 (continuous)	14,842	73.6%	385	2.6%
Sex				
Male	13,406	66.5%	254	1.9%
Female	6,758	33.5%	187	2.8%
Clinically Derived Factors				
American Society of Anesthesiologists (ASA) Class 5[1]	137	0.7%	21	15.3%
ASA Emergency Indicator	993	4.9%	58	5.8%
Ejection Fraction				
<20%	357	1.8%	24	6.7%
20 to 39%	2,707	13.4%	111	4.1%
Left Main Stenosis – Number of Percentage Points >49% (continuous)	4,395	21.8%	115	2.6%
Preoperative Acute Renal Failure	222	1.1%	24	10.8%
Preoperative Cardiogenic Shock	153	0.8%	35	22.9%
Right Coronary Artery Stenosis – Number of Percentage Points >49% (continuous)	11,245	55.8%	263	2.3%
Sodium 0 to <131 mEq/L	238	1.2%	21	8.8%
ICD-9-CM Code Factors				
AMI Initial Episode of Care	3,613	17.9%	129	3.6%
Chronic Kidney Disease				
Stage I to IV (mild to severe)	2,972	14.7%	119	4.0%
Stage V to End Stage Renal Disease (failure)	424	2.1%	31	7.3%
Excision of Other Lesion[2] Same Day as First Valve with or without CABG	682	3.4%	29	4.3%
Heart Failure	5,866	29.1%	255	4.3%
Heart Valve Disease	3,649	18.1%	146	4.0%
History of CABG or Valve Surgery	1,211	6.0%	48	4.0%
History of Peripheral Vascular Disease	2,996	14.9%	96	3.2%
Liver Disease	412	2.0%	29	7.0%
Malnutrition	929	4.6%	68	7.3%
Morbid Obesity	1,737	8.6%	40	2.3%
Other Open Heart Procedure Same Day as First CABG/Valve Surgery	715	3.5%	39	5.5%
Oxygen Therapy Dependence (long-term)	386	1.9%	35	9.1%
PTCA/Stent Prior to First CABG/Valve Surgery Date	296	1.5%	19	6.4%
PTCA/Stent Same Day as First CABG/Valve Surgery	170	0.8%	14	8.2%
Variables tested, but not retained in the model.				
Clinically Derived Factors				
Albumin 0 to <3.1 g/dL	510	2.5%	32	6.3%
Alkaline Phosphatase ≥116 U/L	531	2.6%	32	6.0%
AST ≥61 U/L	688	3.4%	29	4.2%
Bilirubin ≥1.1 mg/dL	984	4.9%	37	3.8%
BNP ≥101 pg/mL / ProBNP ≥1001 pg/mL[3]	1,378	6.8%	77	5.6%
BUN ≥26 mg/dL	1,943	9.6%	112	5.8%
Calcium 0 to <8.5 mg/dL	1,329	6.6%	62	4.7%

DATA TABLES

Candidate Variable	Cases N = 20,164		In-Hospital Mortality 2.2%	
	Number	Percent	Number	Percent
TABLE 4. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – IN-HOSPITAL MORTALITY *CONTINUED*				
CPK-MB ≥5 ng/mL / Troponin I ≥0.41 ng/mL[4]	2,649	13.1%	90	3.4%
Creatinine ≥1.5 mg/dL	1,398	6.9%	78	5.6%
Glucose ≥241 mg/dL	1,503	7.5%	53	3.5%
Hemoglobin 0 to <11.1 g/dL	1,630	8.1%	73	4.5%
pH 0 to <7.36 (arterial)	333	1.7%	17	5.1%
Platelet Count 0 to <150.1 10^9/L	1,420	7.0%	50	3.5%
Potassium				
0 to <3.3 mEq/L	275	1.4%	14	5.1%
≥5.0 mEq/L	526	2.6%	26	4.9%
PT ≥13.1 sec / INR ≥1.11 (ratio) [5]	2,204	10.9%	92	4.2%
PTT ≥55.1 sec	1,622	8.0%	60	3.7%
WBC ≥14.2 10^9/L	640	3.2%	39	6.1%
ICD-9-CM Code Factors				
Anemia	837	4.2%	35	4.2%
Cardiac Adhesions	200	1.0%	10	5.0%
Cardiomyopathy	1,783	8.8%	55	3.1%
Cerebrovascular Disease	1,266	6.3%	38	3.0%
Chronic Lung Disease	3,634	18.0%	104	2.9%
Chronic Pulmonary Hypertension	2,340	11.6%	91	3.9%
Coronary Artery Disease	1,989	9.9%	57	2.9%
Excision of Left Atrial Appendage (LAA)[6] Same Day as First Valve with or without CABG	651	3.2%	28	4.3%
History of Pacemaker or Defibrillator	911	4.5%	36	4.0%
Intra-Aortic Balloon Pump Prior to First CABG/Valve Surgery Date	743	3.7%	28	3.8%
Ischemic Heart Disease	1,938	9.6%	65	3.4%
Multiple Valve Same Day as First CABG/Valve Surgery	1,090	5.4%	55	5.0%
Osteoporosis	550	2.7%	17	3.1%
Type of Valve Procedure – Aortic, Same Day as First CABG/Valve Surgery	5,221	25.9%	138	2.6%
Type of Valve Procedure – Mitral, Same Day as First CABG/Valve Surgery	1,739	8.6%	55	3.2%
Valve Replacement Same Day as First CABG/Valve Surgery	6,744	33.4%	229	3.4%
Variables considered, but not tested in the initial model because initial analysis did not indicate that they were predictive of mortality for this particular data set.				
Demographic Factors				
Race/Ethnicity				
Black	990	4.9%	24	2.4%
Hispanic	505	2.5%	14	2.8%
Other	1,068	5.3%	24	2.2%
White	17,601	87.3%	379	2.2%
Clinically Derived Factors				
Circumflex (and branches) Percent Stenosis				
A 80%-100%	7,812	38.7%	171	2.2%
B 50%-79%	3,011	14.9%	66	2.2%
C 1%-49%	2,104	10.4%	42	2.0%
D 0%	2,086	10.3%	39	1.9%
Missing	5,151	25.5%	123	2.4%
Left Anterior Descending (and branches) Percent Stenosis				
A 80%-100%	9,792	48.6%	202	2.1%
B 50%-79%	3,370	16.7%	74	2.2%
C 1%-49%	1,869	9.3%	49	2.6%
D 0%	1,458	7.2%	24	1.6%
Missing	3,675	18.2%	92	2.5%

DATA TABLES

Candidate Variable		Cases N = 20,164		In-Hospital Mortality 2.2%	
		Number	Percent	Number	Percent
TABLE 4. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – IN-HOSPITAL MORTALITY *CONTINUED*					
Base Units (mEq/L) (arterial)					
A <-11.4		22	0.1%	1	4.5%
B -11.4 to <-4.9		119	0.6%	6	5.0%
C -4.9 to <-1.6		252	1.2%	8	3.2%
D -1.6 to <8.1 (typical)		1,032	5.1%	28	2.7%
E ≥8.1		23	0.1%	1	4.3%
Missing		18,716	92.8%	397	2.1%
Bicarbonate (mEq/L) (arterial)					
A 0 to <18		66	0.3%	5	7.6%
B 18 to <22		247	1.2%	9	3.6%
C 22 to <27 (typical)		894	4.4%	18	2.0%
D 27 to <31		273	1.4%	8	2.9%
E ≥31		35	0.2%	2	5.7%
Missing		18,649	92.5%	399	2.1%
CPK (U/L)					
A 0 to <26		46	0.2%	1	2.2%
B 26 to <36		113	0.6%	6	5.3%
C 36 to <301 (typical)		2,821	14.0%	92	3.3%
D 301 to <501		340	1.7%	6	1.8%
E ≥501		500	2.5%	19	3.8%
Missing		16,344	81.1%	317	1.9%
Neutrophils Band (%)					
A 0 to <7 (typical)		402	2.0%	19	4.7%
B 7 to <14		67	0.3%	2	3.0%
C 14 to <23		14	0.1%	0	0.0%
D 23 to <33		6	<0.1%	0	0.0%
E 33 to100		7	<0.1%	1	14.3%
Missing		19,668	97.5%	419	2.1%
O_2 Sat / pO_2 (mmHg) (arterial) [7]					
O_2 Sat	pO_2				
A 0 to <79	A 0 to <45.1	76	0.4%	9	11.8%
B 79 to <86	B 45.1 to <50.1	28	0.1%	1	3.6%
C 86 to <90	C 50.1 to <55.1	36	0.2%	0	0.0%
D 90 to <99 (typical)	D 55.1 to <141	1,440	7.1%	37	2.6%
E 99 to 100	E ≥141	134	0.7%	6	4.5%
Missing	Missing	18,450	91.5%	388	2.1%
pCO_2 (mmHg) (arterial)					
A 0 to <31		141	0.7%	10	7.1%
B 31 to <36		333	1.7%	10	3.0%
C 36 to <51 (typical)		1,063	5.3%	23	2.2%
D 51 to <61		79	0.4%	5	6.3%
E ≥61		40	0.2%	3	7.5%
Missing		18,508	91.8%	390	2.1%
ICD-9-CM Code Factors					
AMI Subsequent Episode of Care		348	1.7%	8	2.3%
Alcohol-Related Disorders		493	2.4%	8	1.6%
Angina		1,059	5.3%	8	0.8%
Angina, Unstable		2,933	14.5%	33	1.1%
Cancer		589	2.9%	18	3.1%
Cancer of the Respiratory System and Intrathoracic Organs		40	0.2%	2	5.0%
Cardiac Assist Device Prior to First CABG/Valve Surgery Date		11	0.1%	0	0.0%
Cardiopulmonary Resuscitation (CPR) Prior to First CABG/Valve Surgery Date		46	0.2%	0	0.0%

DATA TABLES

Candidate Variable	Cases N = 20,164		In-Hospital Mortality 2.2%	
	Number	Percent	Number	Percent
TABLE 4. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – IN-HOSPITAL MORTALITY *CONTINUED*				
Coagulopathy	176	0.9%	5	2.8%
Congenital Heart Anomalies	978	4.9%	18	1.8%
Dental Extraction Prior to First CABG/Valve Surgery Date	132	0.7%	7	5.3%
Diabetes	7,577	37.6%	150	2.0%
Extracorporeal Membrane Oxygenation (ECMO) Prior to First CABG/Valve Surgery Date	5	<0.1%	2	40.0%
Gastroparesis	87	0.4%	2	2.3%
History of Cancer	2,252	11.2%	35	1.6%
History of Chronic Steroid Use	144	0.7%	3	2.1%
History of Lower Extremity Amputation	153	0.8%	6	3.9%
History of PTCA/Stent	2,810	13.9%	44	1.6%
History of Stroke	1,582	7.8%	36	2.3%
History of Thrombosis or Embolism	602	3.0%	12	2.0%
Hypercholesterolemia	14,258	70.7%	216	1.5%
Hypertension	12,824	63.6%	187	1.5%
Illegal Drug-Related Disorders	206	1.0%	1	0.5%
Long-term Use of Anticoagulants and Antiplatelets	1,482	7.3%	19	1.3%
Long-term Use of Insulin	940	4.7%	14	1.5%
Lupus Erythematosus, Systemic	78	0.4%	1	1.3%
Mental Disorders	3,338	16.6%	61	1.8%
Myocardial Infarction, Old	2,660	13.2%	41	1.5%
Non-Invasive Mechanical Ventilation (NIMV) Prior to First CABG/Valve Surgery Date	78	0.4%	4	5.1%
Obstructive Sleep Apnea and Obesity-Related Hypoventilation Syndrome	2,178	10.8%	40	1.8%
Percutaneous Valve Replacement Prior to First CABG/Valve Surgery Date	0	0.0%	0	0.0%
Percutaneous Valve Replacement Same Day as First CABG/Valve Surgery	24	0.1%	3	12.5%
Type of Valve Procedure – Annuloplasty, Same Day as First CABG/Valve Surgery	515	2.6%	12	2.3%
Type of Valve Procedure – Pulmonary, Same Day as First CABG/Valve Surgery	20	0.1%	0	0.0%
Type of Valve Procedure – Tricuspid, Same Day as First CABG/Valve Surgery	46	0.2%	5	10.9%

[1] ASA Class 5 refers to a moribund (state of near-death) patient who is not expected to survive without the operation.

[2] Excision of Other Lesion includes procedures to treat cardiac dysrhythmias using electrical current, freezing, or cutting (cardiac ablation) and procedures to remove cardiac lesions (tumor, cyst, or mass).

[3] The BNP and pro-BNP analytes were combined to one factor. If a record had both test results, then the factor was based on the BNP.

[4] The CPK-MB and Troponin I analytes were combined to one factor. If a record had both test results, then the factor was based on the Troponin I.

[5] The PT and INR analytes were combined to one factor. If a record had both test results, then the factor was based on the INR.

[6] Closure of a small pouch in the left atrium (left upper chamber in heart) to prevent strokes in patients with atrial fibrillation.

[7] O_2 Saturation and pO_2 were combined to one factor. If a record had both test results, then the factor is based on the pO_2.

DATA TABLES

TABLE 5. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – 30-DAY READMISSIONS

Candidate Variable	Cases N = 16,694		30-Day Readmission 13.6%	
	Number	Percent	Number	Percent
Variables tested and retained in the model.				
Procedure Group Factor				
CABG without Valve	9,826	58.9%	1,174	11.9%
Valve without CABG	4,432	26.5%	663	15.0%
Valve with CABG	2,436	14.6%	438	18.0%
Demographic Factors				
Age (continuous)	16,694	Average Age – 67.4 (Female 69.3, Male 66.4)		
Age – Number of Years >75 (continuous)	4,425	26.5%	784	17.7%
Sex				
Male	11,085	66.4%	1,352	12.2%
Female	5,609	33.6%	923	16.5%
Race/Ethnicity				
Black	839	5.0%	157	18.7%
Hispanic	320	1.9%	63	19.7%
Other	750	4.5%	120	16.0%
White	14,785	88.6%	1,935	13.1%
Clinically Derived Factors				
American Society of Anesthesiologists (ASA) Class 4 or 5[1]	12,158	72.8%	1,772	14.6%
Preoperative Acute Renal Failure	178	1.1%	47	26.4%
Hemoglobin 0 to <11.1 g/dL	1,303	7.8%	298	22.9%
Sodium 0 to <136 mEq/L	1,408	8.4%	281	20.0%
ICD-9-CM Code Factors				
Chronic Kidney Disease				
Stage I to IV (mild to severe)	2,428	14.5%	448	18.5%
Stage V to End Stage Renal Disease (failure)	334	2.0%	101	30.2%
Chronic Lung Disease	3,012	18.0%	493	16.4%
Coagulopathy	135	0.8%	31	23.0%
Diabetes				
Diabetes with Complications	1,236	7.4%	224	18.1%
Diabetes without Complications	5,105	30.6%	748	14.7%
Excision of Other Lesion[2] Same Day as First Valve with or without CABG	543	3.3%	117	21.5%
Heart Failure	4,563	27.3%	887	19.4%
History of Thrombosis or Embolism	512	3.1%	95	18.6%
Malnutrition	723	4.3%	160	22.1%
Mental Disorders	2,790	16.7%	454	16.3%
Morbid Obesity	1,459	8.7%	237	16.2%
Variables tested, but not retained in the model.				
Clinically Derived Factors				
Ejection Fraction <30%	1,059	6.3%	186	17.6%
Preoperative Cardiogenic Shock	93	0.6%	19	20.4%
Albumin 0 to <3.4 g/dL	1,016	6.1%	194	19.1%
Alkaline Phosphatase ≥116 U/L	432	2.6%	87	20.1%
AST ≥31 U/L	1,719	10.3%	276	16.1%
Bilirubin ≥0.9 mg/dL	1,401	8.4%	241	17.2%
BNP ≥101 pg/mL / ProBNP ≥1001 pg/mL[3]	1,138	6.8%	239	21.0%
BUN ≥26 mg/dL	1,546	9.3%	349	22.6%
Calcium 0 to <8.7 mg/dL	1,741	10.4%	298	17.1%
Creatinine ≥1.5 mg/dL	1,126	6.7%	256	22.7%
Glucose ≥136 mg/dL	4,138	24.8%	683	16.5%
Platelet Count 0 to <150.1 10^9/L	1,122	6.7%	191	17.0%

DATA TABLES

Candidate Variable	Cases N = 16,694		30-Day Readmission 13.6%	
	Number	Percent	Number	Percent
TABLE 5. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – 30-DAY READMISSIONS *CONTINUED*				
Potassium				
0 to <3.3 mEq/L	222	1.3%	40	18.0%
≥5.0 mEq/L	427	2.6%	90	21.1%
PT ≥13.1 sec / INR ≥1.11 (ratio) [4]	1,731	10.4%	323	18.7%
PTT ≥35.1 sec	2,566	15.4%	394	15.4%
WBC ≥11.0 10^9/L	1,413	8.5%	242	17.1%
ICD-9-CM Code Factors				
Anemia	684	4.1%	147	21.5%
Cardiac Adhesions	170	1.0%	37	21.8%
Cardiomyopathy	1,448	8.7%	225	15.5%
Chronic Pulmonary Hypertension	1,842	11.0%	352	19.1%
Coronary Artery Disease	1,593	9.5%	261	16.4%
Excision of Left Atrial Appendage (LAA)[5] Same Day as First Valve with or without CABG	533	3.2%	109	20.5%
Heart Valve Disease	2,919	17.5%	479	16.4%
History of CABG/Valve Surgery	1,003	6.0%	166	16.6%
History of Pacemaker or Defibrillator	719	4.3%	133	18.5%
History of Peripheral Vascular Disease	2,438	14.6%	373	15.3%
History of Stroke	1,295	7.8%	215	16.6%
Ischemic Heart Disease	1,546	9.3%	239	15.5%
Liver Disease	315	1.9%	58	18.4%
Long-term Use of Insulin	790	4.7%	129	16.3%
Multiple Valve Same Day as First CABG/Valve Surgery	860	5.2%	176	20.5%
Obstructive Sleep Apnea and Obesity-Related Hypoventilation Syndrome	1,827	10.9%	278	15.2%
Osteoporosis	459	2.7%	78	17.0%
Oxygen Therapy Dependence (long-term)	283	1.7%	64	22.6%
Type of Valve Procedure – Annuloplasty, Same Day as First CABG/Valve Surgery	417	2.5%	82	19.7%
Type of Valve Procedure – Aortic, Same Day as First CABG/Valve Surgery	4,250	25.5%	630	14.8%
Type of Valve Procedure – Mitral, Same Day as First CABG/Valve Surgery	1,359	8.1%	224	16.5%
Valve Replacement Same Day as First CABG/Valve Surgery	5,436	32.6%	865	15.9%
Variables considered, but not tested in the initial model because the initial analysis did not indicate that they were predictive of readmission for this particular data set.				
Clinically Derived Factors				
ASA Emergency Indicator	781	4.7%	106	13.6%
Circumflex (and branches) Percent Stenosis				
A 80%-100%	6,526	39.1%	869	13.3%
B 50%-79%	2,525	15.1%	335	13.3%
C 1%-49%	1,774	10.6%	243	13.7%
D 0%	1,718	10.3%	251	14.6%
Missing	4,151	24.9%	577	13.9%
Left Anterior Descending (and branches) Percent Stenosis				
A 80%-100%	8,217	49.2%	1,081	13.2%
B 50%-79%	2,829	16.9%	370	13.1%
C 1%-49%	1,555	9.3%	250	16.1%
D 0%	1,186	7.1%	155	13.1%
Missing	2,907	17.4%	419	14.4%

DATA TABLES

Candidate Variable		Cases N = 16,694		30-Day Readmission 13.6%	
		Number	Percent	Number	Percent
TABLE 5. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – 30-DAY READMISSIONS *CONTINUED*					
Left Main Percent Stenosis					
A 80%-100%		1,498	9.0%	179	11.9%
B 50%-79%		2,162	13.0%	287	13.3%
C 1%-49%		2,155	12.9%	325	15.1%
D 0%		3,499	21.0%	465	13.3%
Missing		7,380	44.2%	1,019	13.8%
Right Coronary Artery (and branches) Percent Stenosis					
A 80%-100%		7,047	42.2%	974	13.8%
B 50%-79%		2,374	14.2%	337	14.2%
C 1%-49%		1,954	11.7%	261	13.4%
D 0%		1,546	9.3%	203	13.1%
Missing		3,773	22.6%	500	13.3%
Base Units (mEq/L) (arterial)					
A <-11.4		17	0.1%	2	11.8%
B -11.4 to <-4.9		88	0.5%	15	17.0%
C -4.9 to <-1.6		189	1.1%	28	14.8%
D -1.6 to <8.1 (typical)		873	5.2%	136	15.6%
E ≥8.1		20	0.1%	5	25.0%
Missing		15,507	92.9%	2,089	13.5%
Bicarbonate (mEq/L) (arterial)					
A 0 to <18		49	0.3%	6	12.2%
B 18 to <22		205	1.2%	34	16.6%
C 22 to <27 (typical)		774	4.6%	107	13.8%
D 27 to <31		228	1.4%	46	20.2%
E ≥31		31	0.2%	4	12.9%
Missing		15,407	92.3%	2,078	13.5%
CPK-MB ng/mL / Troponin I ng/mL[6]					
CPK-MB	Troponin I				
A 0 to <5 (typical)	A 0 to <0.41 (typical)	2,566	15.4%	415	16.2%
B 5 to <6	B 0.41 to <0.71	254	1.5%	37	14.6%
C 6 to <10	C 0.71 to <1.01	247	1.5%	35	14.2%
D 10 to <16	D 1.01 to <1.51	220	1.3%	29	13.2%
E ≥16	E ≥1.51	1,473	8.8%	221	15.0%
Missing	Missing	11,934	71.5%	1,538	12.9%
CPK (U/L)					
A 0 to <26		37	0.2%	10	27.0%
B 26 to <36		95	0.6%	25	26.3%
C 36 to <301 (typical)		2,351	14.1%	331	14.1%
D 301 to <501		287	1.7%	48	16.7%
E ≥501		405	2.4%	51	12.6%
Missing		13,519	81.0%	1,810	13.4%
Neutrophils Band (%)					
A 0 to <7 (typical)		316	1.9%	51	16.1%
B 7 to <14		53	0.3%	5	9.4%
C 14 to <23		12	0.1%	4	33.3%
D 23 to <33		5	<0.1%	1	20.0%
E 33 to100		5	<0.1%	0	0.0%
Missing		16,303	97.7%	2,214	13.6%

DATA TABLES

Candidate Variable		Cases N = 16,694		30-Day Readmission 13.6%	
		Number	Percent	Number	Percent
TABLE 5. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – 30-DAY READMISSIONS *CONTINUED*					
O_2 Sat / pO_2 (mmHg) (arterial) [7]					
O_2 Sat	pO_2				
A 0 to <79	A 0 to <45.1	53	0.3%	6	11.3%
B 79 to <86	B 45.1 to <50.1	23	0.1%	1	4.3%
C 86 to <90	C 50.1 to <55.1	33	0.2%	6	18.2%
D 90 to <99	D 55.1 to <141 (typical)	1,192	7.1%	194	16.3%
E 99 to 100	E ≥141	111	0.7%	20	18.0%
Missing	Missing	15,282	91.5%	2,048	13.4%
pH (arterial)					
A 0 to <7.21		44	0.3%	6	13.6%
B 7.21 to <7.31		91	0.5%	22	24.2%
C 7.31 to <7.36		106	0.6%	15	14.2%
D 7.36 to <7.49 (typical)		1,074	6.4%	152	14.2%
E 7.49 to 14		68	0.4%	21	30.9%
Missing		15,311	91.7%	2,059	13.4%
pCO_2 (mmHg) (arterial)					
A 0 to <31		114	0.7%	20	17.5%
B 31 to <36		267	1.6%	48	18.0%
C 36 to <51 (typical)		894	5.4%	132	14.8%
D 51 to <61		59	0.4%	12	20.3%
E ≥61		31	0.2%	4	12.9%
Missing		15,329	91.8%	2,059	13.4%
ICD-9-CM Code Factors					
AMI Initial Episode of Care		2,939	17.6%	422	14.4%
AMI Subsequent Episode of Care		292	1.7%	35	12.0%
Alcohol-Related Disorders		421	2.5%	53	12.6%
Angina		911	5.5%	105	11.5%
Angina, Unstable		2,503	15.0%	277	11.1%
Cancer		468	2.8%	67	14.3%
Cancer of the Respiratory System and Intrathoracic Organs		30	0.2%	6	20.0%
Cardiac Assist Device Prior to First CABG/Valve Surgery Date		9	0.1%	0	0.0%
Cardiopulmonary Resuscitation (CPR) Prior to First CABG/Valve Surgery Date		37	0.2%	13	35.1%
Cerebrovascular Disease		1,056	6.3%	138	13.1%
Congenital Heart Anomalies		791	4.7%	80	10.1%
Dental Extraction Prior to First CABG/Valve Surgery Date		100	0.6%	21	21.0%
Extracorporeal Membrane Oxygenation (ECMO) Prior to First CABG/Valve Surgery Date		1	<0.1%	0	0.0%
Gastroparesis		73	0.4%	14	19.2%
History of Cancer		1,835	11.0%	240	13.1%
History of Chronic Steroid Use		119	0.7%	15	12.6%
History of Lower Extremity Amputation		122	0.7%	20	16.4%
History of PTCA/Stent		2,334	14.0%	316	13.5%
Hypercholesterolemia		11,946	71.6%	1,551	13.0%
Hypertension		10,748	64.4%	1,331	12.4%
Illegal Drug-Related Disorders		176	1.1%	33	18.8%
Intra-Aortic Balloon Pump Prior to First CABG/Valve Surgery Date		602	3.6%	88	14.6%
Long-term Use of Anticoagulants and Antiplatelets		1,207	7.2%	170	14.1%
Lupus Erythematosus, Systemic		63	0.4%	5	7.9%
Myocardial Infarction, Old		2,207	13.2%	298	13.5%
Non-Invasive Mechanical Ventilation (NIMV) Prior to First CABG/Valve Surgery Date		61	0.4%	12	19.7%

DATA TABLES

Candidate Variable	Cases N = 16,694		30-Day Readmission 13.6%	
	Number	Percent	Number	Percent
TABLE 5. FREQUENCY DATA FOR POTENTIAL RISK FACTORS – 30-DAY READMISSIONS *CONTINUED*				
Other Open Heart Procedure Same Day as First CABG/Valve Surgery	583	3.5%	82	14.1%
Percutaneous Valve Replacement Prior to First CABG/Valve Surgery Date	0	0.0%	0	0.0%
Percutaneous Valve Replacement Same Day as First CABG/Valve Surgery	16	0.1%	5	31.3%
PTCA/Stent Prior to First CABG/Valve Surgery Date	240	1.4%	37	15.4%
PTCA/Stent Same Day as First CABG/Valve Surgery	130	0.8%	20	15.4%
Type of Valve Procedure – Pulmonary, Same Day as First CABG/Valve Surgery	16	0.1%	2	12.5%
Type of Valve Procedure – Tricuspid, Same Day as First CABG/Valve Surgery	30	0.2%	6	20.0%

[1] ASA Class 4 or 5 refers to a patient with severe systemic disease that is a constant threat to life or a moribund (state of near-death) patient who is not expected to survive without the operation, respectively.

[2] Excision of Other Lesion includes procedures to treat cardiac dysrhythmias using electrical current, freezing, or cutting (cardiac ablation) and procedures to remove cardiac lesions (tumor, cyst, or mass).

[3] The BNP and pro-BNP analytes were combined to one factor. If a record had both test results, then the factor was based on the BNP.

[4] The PT and INR analytes were combined to one factor. If a record had both test results, then the factor was based on the INR.

[5] Closure of a small pouch in the left atrium (left upper chamber in heart) to prevent strokes in patients with atrial fibrillation.

[6] The CPK-MB and Troponin I analytes were combined to one factor. If a record had both test results, then the factor was based on the Troponin I.

[7] O_2 Saturation and pO_2 were combined to one factor. If a record had both test results, then the factor is based on the pO_2.

DATA TABLES

TABLE 6. IN-HOSPITAL MORTALITY MODEL

The c-statistic for the model is 0.82425.

Predictor	Coefficient	Odds Ratio*	p-value
Intercept	-6.1001		
Procedure Group Factor			<0.0001
Valve without CABG	0.3162	1.372	
Valve with CABG	0.9009	2.462	
Demographic Factors			
Age (continuous)	0.0006	1.006	0.9726
Age – Number of Years >60 (continuous)	0.0558	1.322	0.0169
Female	0.1944	1.215	0.0698
Clinically Derived Factors			
American Society of Anesthesiologists (ASA) Class 5	0.9059	2.474	0.0059
ASA Emergency Indicator	0.5671	1.763	0.0039
Ejection Fraction			0.0051
<20%	0.5989	1.820	
20 to 39%	0.3497	1.419	
Left Main Stenosis – Number of Percentage Points >49% (continuous)	0.0105	1.111	0.0075
Preoperative Acute Renal Failure	0.4833	1.621	0.0770
Preoperative Cardiogenic Shock	1.2334	3.433	<0.0001
Right Coronary Artery Stenosis – Number of Percentage Points >49% (continuous)	0.0027	1.027	0.3052
Sodium 0 to <131 mEq/L	0.7803	2.182	0.0050
ICD-9-CM Code Factors			
AMI Initial Episode of Care	0.3970	1.487	0.0039
Chronic Kidney Disease			<0.0001
Stage I to IV (mild to severe)	0.3101	1.364	
Stage V to End Stage Renal Disease (failure)	1.1636	3.201	
Excision of Other Lesion Same Day as First Valve with or without CABG	0.6074	1.836	0.0069
Heart Failure	0.4617	1.587	<0.0001
Heart Valve Disease	0.4185	1.520	0.0002
History of CABG or Valve Surgery	0.4687	1.598	0.0084
History of Peripheral Vascular Disease	0.2601	1.297	0.0392
Liver Disease	1.5315	4.625	<0.0001
Malnutrition	0.6185	1.856	<0.0001
Morbid Obesity	0.3902	1.477	0.0349
Other Open Heart Procedure Same Day as First CABG/Valve Surgery	0.6967	2.007	0.0005
Oxygen Therapy Dependence (long-term)	0.8499	2.339	0.0001
PTCA/Stent Prior to First CABG/Valve Surgery Date	1.3679	3.927	<0.0001
PTCA/Stent Same Day as First CABG/Valve Surgery	0.9130	2.492	0.0122

* With the exception of “Age – Number of Years >60”, which is calculated at units of 5, odds ratios for continuous variables are calculated at a unit of 10. Using “Left Main Stenosis – Number of Percentage Points >49%” as an example, the risk for death is about 11% higher for patients with 60% stenosis than for patients with 50% stenosis.

DATA TABLES

TABLE 7. 30-DAY READMISSIONS MODEL

The c-statistic for the model is 0.64595.

Predictor	Coefficient	Odds Ratio	p-value
Intercept	-3.2519		
Procedure Group Factor			0.0002
Valve without CABG	0.1109	1.117	
Valve with CABG	0.2707	1.311	
Demographic Factors			
Age (continuous)	0.0090	1.094	0.0031
Age – Number of Years >75 (continuous)	0.0338	1.184	0.0004
Female	0.1561	1.169	0.0016
Race/Ethnicity			<0.0001
Black	0.3364	1.400	
Hispanic	0.5578	1.747	
Other	0.2628	1.301	
Clinically Derived Factors			
American Society of Anesthesiologists (ASA) Class 4 or 5	0.1963	1.217	0.0004
Preoperative Acute Renal Failure	0.3144	1.370	0.0889
Hemoglobin 0 to <11.1 g/dL	0.2385	1.269	0.0024
Sodium 0 to <136 mEq/L	0.3058	1.358	<0.0001
ICD-9-CM Code Factors			
Chronic Kidney Disease			<0.0001
Stage I to IV (mild to severe)	0.1709	1.186	
Stage V to End Stage Renal Disease (failure)	0.7783	2.178	
Chronic Lung Disease	0.1733	1.189	0.0028
Coagulopathy	0.5434	1.722	0.0154
Diabetes			0.0147
Diabetes with Complications	0.2033	1.225	
Diabetes without Complications	0.1196	1.127	
Excision of Other Lesion Same Day as First Valve with or without CABG	0.4783	1.613	<0.0001
Heart Failure	0.3189	1.376	<0.0001
History of Thrombosis or Embolism	0.2244	1.252	0.0681
Malnutrition	0.2657	1.304	0.0070
Mental Disorders	0.2592	1.296	<0.0001
Morbid Obesity	0.1698	1.185	0.0336

* Odds ratios for “Age” is calculated at units of 10 and odds ratios for “Age – Number of Years >75” is calculated at units of 5. Using “Age” as an example, the risk for readmission is about 9% higher for patients age 60 than for patients age 50.

APPENDICES

APPENDIX A: EXCLUSION DEFINITIONS

TABLE A1. CLINICAL COMPLEXITY EXCLUSIONS APPLICABLE TO ALL PROCEDURE GROUPS

ICD-9-CM Code	Description
Diagnosis or procedure in any position	
32.22	Lung volume reduction surgery same day as first CABG/valve surgery
33.50	Lung transplantation, not otherwise specified
33.51	Unilateral lung transplantation
33.52	Bilateral lung transplantation
33.6	Combined heart-lung transplantation
35.42	Creation of septal defect in heart
35.50	Repair of unspecified septal defect of heart with prosthesis
35.51	Repair of atrial septal defect with prosthesis, open technique
35.53	Repair of ventricular septal defect with prosthesis, open technique
35.54	Repair of endocardial cushion defect with prosthesis
35.60	Repair of unspecified septal defect of heart with tissue graft
35.61	Repair of atrial septal defect with tissue graft
35.62	Repair of ventricular septal defect with tissue graft
35.63	Repair of endocardial cushion defect with tissue graft
35.70	Other and unspecified repair of unspecified septal defect of heart
35.72	Other and unspecified repair of ventricular septal defect
35.73	Other and unspecified repair of endocardial cushion defect
35.81	Total repair of tetralogy of Fallot
35.82	Total repair of total anomalous pulmonary venous connection
35.83	Total repair of truncus arteriosus
35.84	Total correction of transposition of great vessels, not elsewhere classified
35.91	Interatrial transposition of venous return
35.92	Creation of conduit between right ventricle and pulmonary artery
35.93	Creation of conduit between left ventricle and aorta
35.94	Creation of conduit between atrium and pulmonary artery
37.32	Excision of aneurysm of heart
37.35	Partial ventriculectomy
37.51	Heart transplantation
37.52	Implantation of total internal biventricular heart replacement system
37.53	Replacement or repair of thoracic unit of (total) replacement heart system
38.12	Carotid endarterectomy
38.34	Resection of aorta with anastomosis
38.35	Resection of other thoracic vessel with anastomosis
38.36	Resection of abdominal arteries with anastomosis
38.44	Resection of abdominal aorta with replacement
38.45	Resection of other thoracic vessel with replacement
38.46	Resection of abdominal arteries with replacement
39.51	Clipping of aneurysm
39.52	Other repair of aneurysm
39.71	Endovascular implantation of other graft in abdominal aorta
39.73	Endovascular implantation of graft in thoracic aorta
39.78	Endovascular implant of branch or fenestrated graft(s) in aorta

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

ICD-9-CM Code	Description
Diagnosis or procedure in any position	
Table A1: Clinical Complexity Exclusions Applicable to All Procedure Groups *continued*	
41.00	Bone marrow transplant, not otherwise specified
41.02	Allogeneic bone marrow transplant with purging
41.03	Allogeneic bone marrow transplant without purging
41.05	Allogeneic hematopoietic stem cell transplant without purging
41.06	Cord blood stem cell transplant
41.08	Allogeneic hematopoietic stem cell transplant with purging
41.09	Autologous bone marrow transplant with purging
41.94	Transplantation of spleen
46.97	Transplant of intestine
50.51	Auxiliary liver transplant
50.59	Other transplant of liver
52.80	Pancreatic transplant, not otherwise specified
52.82	Homotransplant of pancreas
52.83	Heterotransplant of pancreas
52.85	Allotransplantation of cells of islets of Langerhans
52.86	Transplantation of cells of islets of Langerhans, not otherwise specified
55.61	Renal autotransplantation
55.69	Other kidney transplantation
423.2 plus 37.31	Diagnosis of constrictive pericarditis **and** undergoing pericardiectomy
441.00	Dissection of aorta, unspecified site
441.01	Dissection of aorta, thoracic
996.81	Complications of transplanted kidney
996.82	Complications of transplanted liver
996.83	Complications of transplanted heart
996.84	Complications of transplanted lung
996.85	Complications of bone marrow transplant
996.86	Complications of transplanted pancreas
996.87	Complications of transplanted intestine
996.88	Complications of transplanted stem cell
V42.0	Kidney replaced by transplant
V42.1	Heart replaced by transplant
V42.6	Lung replaced by transplant
V42.7	Liver replaced by transplant
V42.81	Bone marrow transplant
V42.82	Peripheral stem cells replaced by transplant
V42.83	Pancreas transplant
V42.84	Intestine transplant
V43.21	Heart replacement by heart assist device
V43.22	Heart replacement by fully implantable artificial heart

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

TABLE A2. ADDITIONAL CLINICAL COMPLEXITY EXCLUSIONS APPLICABLE TO CABG WITHOUT VALVE PROCEDURE GROUP

ICD-9-CM Code	Description
Procedure in any position:	
35.31	Operations on papillary muscle
35.32	Operations on chordae tendineae
35.34	Infundibulectomy
35.35	Operations on trabeculae carneae cordis
35.39	Operations on other structures adjacent to valves of heart
35.71	Other and unspecified repair of atrial septal defect
35.95	Revision of corrective procedure on heart
35.98	Other operations on septa of heart
36.91	Repair of aneurysm of coronary vessel
37.33	Excision or destruction of other lesion or tissue of heart, open approach
37.36	Excision, destruction or exclusion of left atrial appendage (LAA)

TABLE A3: ADDITIONAL CLINICAL COMPLEXITY EXCLUSIONS APPLICABLE TO VALVE WITHOUT CABG PROCEDURE GROUP

ICD-9-CM Code	Description
Principal diagnosis only:	
036.42	Meningococcal endocarditis
038.x & 038.xx	Septicemia
074.22	Coxsackie endocarditis
093.20	Syphilitic endocarditis, valve unspecified
093.21	Syphilitic endocarditis, mitral valve
093.22	Syphilitic endocarditis, aortic valve
093.23	Syphilitic endocarditis, tricuspid valve
093.24	Syphilitic endocarditis, pulmonary valve
098.84	Gonococcal endocarditis
112.81	Candidal endocarditis
115.04	Histoplasmosis capsulatum endocarditis
115.14	Histoplasmosis duboisii endocarditis
115.94	Histoplasmosis endocarditis
391.1	Acute rheumatic endocarditis
421.0	Acute and subacute bacterial endocarditis
421.1	Acute and subacute infective endocarditis in diseases classified elsewhere
421.9	Acute endocarditis, unspecified
424.90	Endocarditis, valve unspecified, unspecified cause
424.91	Endocarditis in diseases classified elsewhere
424.99	Endocarditis, valve unspecified, specified cause except rheumatic
996.02	Mechanical complication due to heart valve prosthesis
996.61	Infection and inflammatory reaction due to cardiac device/implant/graft
996.71	Other complications due to heart valve prosthesis
Diagnosis in any position:	
277.30 plus 425.7	Amyloidosis, unspecified **and** nutritional & metabolic cardiomyopathy
277.39 plus 425.7	Other amyloidosis **and** plus nutritional & metabolic cardiomyopathy
414.10	Aneurysm of heart (wall)
414.19	Other aneurysm of heart

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

TABLE A4: ADDITIONAL CLINICAL COMPLEXITY EXCLUSIONS APPLICABLE TO VALVE WITH CABG PROCEDURE GROUP

ICD-9-CM Code	Description
Principal diagnosis only	
036.42	Meningococcal endocarditis
038.x & 038.xx	Septicemia
074.22	Coxsackie endocarditis
093.20	Syphilitic endocarditis, valve unspecified
093.21	Syphilitic endocarditis, mitral valve
093.22	Syphilitic endocarditis, aortic valve
093.23	Syphilitic endocarditis, tricuspid valve
093.24	Syphilitic endocarditis, pulmonary valve
098.84	Gonococcal endocarditis
112.81	Candidal endocarditis
115.04	Histoplasmosis capsulatum endocarditis
115.14	Histoplasmosis duboisii endocarditis
115.94	Histoplasmosis endocarditis
391.1	Acute rheumatic endocarditis
421.0	Acute and subacute bacterial endocarditis
421.1	Acute and subacute infective endocarditis in diseases classified elsewhere
421.9	Acute endocarditis, unspecified
424.90	Endocarditis, valve unspecified, unspecified cause
424.91	Endocarditis in diseases classified elsewhere
424.99	Endocarditis, valve unspecified, specified cause except rheumatic
996.02	Mechanical complication due to heart valve prosthesis
996.61	Infection and inflammatory reaction due to cardiac device/implant/graft
996.71	Other complications due to heart valve prosthesis
Diagnosis in any position:	
277.30 plus 425.7	Amyloidosis, unspecified **and** nutritional & metabolic cardiomyopathy
277.39 plus 425.7	Other amyloidosis **and** plus nutritional & metabolic cardiomyopathy
414.10	Aneurysm of heart (wall)
414.19	Other aneurysm of heart
Procedure in any position:	
35.95	Revision of corrective procedure on heart
35.98	Other operations on septa of heart
36.91	Repair of aneurysm of coronary vessel

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

TABLE A5. MS-DRG CRITERIA FOR STUDY POPULATION DEFINITION

MS-DRGs *Not* Excluded from the Study: CABG without Valve	
MS-DRG 001	Heart Transplant or Implant of Heart Assist System with MCC
MS-DRG 002	Heart Transplant or Implant of Heart Assist System without MCC
MS-DRG 003 and MDC 5*	ECMO or tracheostomy with Mechanical Ventilation 96+ Hours or Principal Diagnosis Except Face, Mouth, Neck with Major O.R. Procedures
MS-DRG 215	Other Heart Assist System Implant
MS-DRG 216	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with MCC
MS-DRG 217	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with CC
MS-DRG 218	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization without CC/MCC
MS-DRG 219	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization with MCC
MS-DRG 220	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization with CC
MS-DRG 221	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization without CC/MCC
MS-DRG 222	Cardiac Defibrillator Implant with Cardiac Catheterization with Acute MI/Heart Failure/Shock with MCC
MS-DRG 223	Cardiac Defibrillator Implant with Cardiac Catheterization with Acute MI/Heart Failure/Shock without MCC
MS-DRG 224	Cardiac Defibrillator Implant with Cardiac Catheterization without Acute MI/Heart Failure/Shock with MCC
MS-DRG 225	Cardiac Defibrillator Implant with Cardiac Catheterization without Acute MI/Heart Failure/Shock without MCC
MS-DRG 226	Cardiac Defibrillator Implant without Cardiac Catheterization with MCC
MS-DRG 227	Cardiac Defibrillator Implant without Cardiac Catheterization without MCC
MS-DRG 228	Other Cardiothoracic Procedures with MCC
MS-DRG 229	Other Cardiothoracic Procedures with CC
MS-DRG 230	Other Cardiothoracic Procedures without CC/MCC
MS-DRG 231	Coronary Bypass with PTCA with MCC
MS-DRG 232	Coronary Bypass with PTCA without MCC
MS-DRG 233	Coronary Bypass with Cardiac Catheterization with MCC
MS-DRG 234	Coronary Bypass with Cardiac Catheterization without MCC
MS-DRG 235	Coronary Bypass without Cardiac Catheterization with MCC
MS-DRG 236	Coronary Bypass without Cardiac Catheterization without MCC
MS-DRGs *Not* Excluded from the Study: Valve without CABG	
MS-DRG 001	Heart Transplant or Implant of Heart Assist System with MCC
MS-DRG 002	Heart Transplant or Implant of Heart Assist System without MCC
MS-DRG 003 and MDC 5*	ECMO or tracheostomy with Mechanical Ventilation 96+ Hours or Principal Diagnosis Except Face, Mouth, Neck with Major O.R. Procedures
MS-DRG 215	Other Heart Assist System Implant
MS-DRG 216	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with MCC
MS-DRG 217	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with CC
MS-DRG 218	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization without CC/MCC
MS-DRG 219	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization with MCC
MS-DRG 220	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization with CC
MS-DRG 221	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization without CC/MCC
MS-DRG 222	Cardiac Defibrillator Implant with Cardiac Catheterization with Acute MI/Heart Failure/Shock with MCC
MS-DRG 223	Cardiac Defibrillator Implant with Cardiac Catheterization with Acute MI/Heart Failure/Shock without MCC
MS-DRG 224	Cardiac Defibrillator Implant with Cardiac Catheterization without Acute MI/Heart Failure/Shock with MCC
MS-DRG 225	Cardiac Defibrillator Implant with Cardiac Catheterization without Acute MI/Heart Failure/Shock without MCC
MS-DRG 226	Cardiac Defibrillator Implant without Cardiac Catheterization with MCC
MS-DRG 227	Cardiac Defibrillator Implant without Cardiac Catheterization without MCC
MS-DRG 228	Other Cardiothoracic Procedures with MCC
MS-DRG 229	Other Cardiothoracic Procedures with CC

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

MS-DRG 230	Other Cardiothoracic Procedures without CC/MCC

TABLE A5. MS-DRG CRITERIA FOR STUDY POPULATION DEFINITION *CONTINUED*

MS-DRGs *Not* Excluded from the Study: Valve *with* CABG	
MS-DRG 001	Heart Transplant or Implant of Heart Assist System with MCC
MS-DRG 002	Heart Transplant or Implant of Heart Assist System without MCC
MS-DRG 003 and MDC 5*	ECMO or tracheostomy with Mechanical Ventilation 96+ Hours or Principal Diagnosis Except Face, Mouth, Neck with Major O.R. Procedures
MS-DRG 215	Other Heart Assist System Implant
MS-DRG 216	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with MCC
MS-DRG 217	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization with CC
MS-DRG 218	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization without CC/MCC
MS-DRG 219	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization with MCC
MS-DRG 220	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization with CC
MS-DRG 221	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization without CC/MCC
MS-DRG 222	Cardiac Defibrillator Implant with Cardiac Catheterization with Acute MI/Heart Failure/Shock with MCC
MS-DRG 223	Cardiac Defibrillator Implant with Cardiac Catheterization with Acute MI/Heart Failure/Shock without MCC
MS-DRG 224	Cardiac Defibrillator Implant with Cardiac Catheterization without Acute MI/Heart Failure/Shock with MCC
MS-DRG 225	Cardiac Defibrillator Implant with Cardiac Catheterization without Acute MI/Heart Failure/Shock without MCC
MS-DRG 226	Cardiac Defibrillator Implant without Cardiac Catheterization with MCC
MS-DRG 227	Cardiac Defibrillator Implant without Cardiac Catheterization without MCC
MS-DRG 228	Other Cardiothoracic Procedures with MCC
MS-DRG 229	Other Cardiothoracic Procedures with CC
MS-DRG 230	Other Cardiothoracic Procedures without CC/MCC

* Major Diagnostic Category (MDC) 5: Diseases and Disorders of the Circulatory System

APPENDIX B: REASONS FOR READMISSIONS DEFINITIONS

A readmission was counted only if the patient was readmitted with a principal diagnosis (i.e., the reason for the readmission) that indicated a heart-related condition, or an infection or a complication. The following list of categories shows the ICD-9-CM codes that were counted as readmissions, when the code was located in the principal diagnosis position.

CIRCULATORY SYSTEM

Cardiac Dysrhythmias

Heart Block
426.0, 426.10, 426.11, 426.12, 426.13, 426.2, 426.3, 426.4, 426.50, 426.51, 426.52, 426.53, 426.54, 426.6, 426.7, 426.81, 426.82, 426.89, 426.9

Paroxysmal Tachycardia
427.0, 427.1, 427.2

Atrial Fibrillation and Atrial Flutter
427.31, 427.32

Ventricular Fibrillation and Ventricular Flutter
427.41, 427.42, 427.5

Premature Heart Beats
427.60, 427.61, 427.69

Other Cardiac Dysrhythmias
427.81, 427.89, 427.9

Heart Failure
398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, 428.9

Functional Disturbances Follow Cardiac Surgery (Postcardiotomy Syndrome)
429.4

Hypertension and Hypotension

Hypertension
401.0, 401.1, 401.9, 402.00, 402.10, 402.90, 405.01, 405.09, 405.11, 405.19, 405.91, 405.99, 997.91

Hypotension
458.0, 458.21, 458.29, 458.8, 458.9, 796.3

Myocardial Infarction and Ischemia

Acute Myocardial Infarction, Initial Episode
410.01, 410.11, 410.21, 410.31, 410.41, 410.51, 410.61, 410.71, 410.81, 410.91

Acute Myocardial Infarction, Unspecified or Subsequent Episode
410.00, 410.02, 410.10, 410.12, 410.20, 410.22, 410.30, 410.32, 410.40, 410.42, 410.50, 410.52, 410.60, 410.62, 410.70, 410.72, 410.80, 410.82, 410.90, 410.92

Other Forms of Myocardial Ischemia
411.0, 411.81, 411.89, 429.79

Angina Pectoris and Chest Pain
411.1, 413.0, 413.1, 413.9, 786.50, 786.51, 786.59

Atherosclerosis

Coronary Atherosclerosis
414.00, 414.01, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 414.2, 414.3, 414.4[2]

Other Atherosclerosis
429.2, 440.0, 440.1, 440.20, 440.21, 440.22, 440.23, 440.24, 440.29, 440.30, 440.31, 440.32, 440.8, 440.9

Heart Aneurysm and Dissection
414.10, 414.11, 414.12, 414.19

Endocarditis, Myocarditis, and Pericarditis
112.81, 397.9, 398.0, 420.90, 420.91, 420.99, 421.0, 421.9, 422.90, 422.91, 422.92, 422.93, 422.99, 423.1, 423.2, 423.3, 423.8, 423.9, 424.90, 424.99, 429.0, 429.1

Heart Valve Disease

Mitral Valve Disease
394.0, 394.1, 394.2, 394.9, 424.0

Aortic Valve Disease
395.0, 395.1, 395.2, 395.9, 424.1

Tricuspid Valve Disease
397.0, 424.2

Pulmonary Valve Disease
397.1, 424.3

APPENDIX B: REASONS FOR READMISSIONS DEFINITIONS *(CONTINUED)*

Multiple Valve Disease
396.0, 396.1, 396.2, 396.3, 396.8, 396.9

Other Endocardial Structure Disease
429.5, 429.6, 429.71, 429.81

Cardiomyopathies
425.0, 425.1[1], 425.11[2], 425.18[2], 425.3, 425.4, 425.9

Other Aneurysm and Dissection

Aortic Aneurysm and Dissection
441.00, 441.01, 441.02, 441.03, 441.1, 441.2, 441.3, 441.4, 441.5, 441.6, 441.7, 441.9

Other Arterial Aneurysm
437.3, 442.0, 442.1, 442.2, 442.3, 442.81, 442.82, 442.83, 442.84, 442.89, 442.9

Other Arterial Dissection
443.21, 443.22, 443.23, 443.24, 443.29

Arterial Embolism and Thrombosis

Abdominal and Thoracic Aorta
444.0[1], 444.01[2], 444.09[2], 444.1

Arteries of the Extremities
444.21, 444.22, 445.01, 445.02

Other Arteries Excluding Precerebral and Cerebral Arteries
444.81, 444.89, 444.9, 445.81, 445.89, 449, 593.81

Venous Embolism and Thrombosis

Lower Extremity Venous Embolism and Thrombosis
453.40, 453.41, 453.42

Renal Vein Embolism and Thrombosis
453.3

Other Venous Embolism and Thrombosis
453.2, 453.6, 453.81, 453.82, 453.83, 453.84, 453.85, 453.86, 453.87, 453.89, 453.9

Phlebitis and Thrombophlebitis

Lower Extremity Phlebitis and Thrombophlebitis
451.0, 451.11, 451.19, 451.2

Upper Extremity Phlebitis and Thrombophlebitis
451.82, 451.83, 451.84

Other Vessel Phlebitis and Thrombophlebitis
451.81, 451.89, 451.9

Occlusion and Stenosis

Precerebral Artery Occlusion and Stenosis
433.00, 433.20, 433.30, 433.80, 433.90

Cerebral Artery Occlusion and Stenosis
433.10, 434.00, 434.10, 434.90

Retinal Artery Occlusion and Visual Loss
362.30, 362.31, 362.32, 362.33, 362.34, 362.35, 362.36, 362.37, 368.11, 368.12, 368.40

Stroke

Ischemic Stroke
433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91

Hemorrhagic Stroke
430, 431, 432.0, 432.1, 432.9

Transient Cerebral Ischemia
435.0, 435.1, 435.2, 435.3, 435.8, 435.9

Postoperative Stroke
997.02

Other Diseases and Symptoms of the Circulatory System
398.90, 398.99, 414.8, 414.9, 423.0, 429.3, 429.82, 429.89, 429.9, 785.0, 785.1, 785.3, V533.1, V533.2, V533.9

RESPIRATORY SYSTEM

Pulmonary Embolism and Infarction

Pulmonary Embolism and Infarction
415.0, 415.12, 415.13[2], 415.19

APPENDIX B: REASONS FOR READMISSIONS DEFINITIONS *(CONTINUED)*

Postoperative Pulmonary Embolism and Infarction
415.11

Pleural Effusion and Atelectasis
511.0, 511.89, 511.9, 518.0

Pneumothorax
Pneumothorax
512.0, 512.8[1], 512.81[2], 512.82[2], 512.84[2], 512.89[2]

Postoperative Pneumothorax
512.1, 512.2[2]

Pulmonary Edema
514, 518.4, 518.5[1], 518.52[2]

Acute Respiratory Failure
518.51[2], 518.53[2], 518.81, 518.82, 518.84, 799.1

Other Diseases and Symptoms of the Respiratory System
518.1, 519.19, 519.2, 733.6, 786.00, 786.02, 786.04, 786.05, 786.06, 786.09, 786.30, 786.39, 786.52, 786.6, 786.7, 786.8, 786.9, 799.02, 998.81

NERVOUS SYSTEM

Encephalopathies
348.30, 348.31, 348.39, 349.82, 437.2

Cerebral Edema and Brain Compression
348.4, 348.5

Anoxic Brain Damage
348.1

Coma and Stupor
780.01, 780.03, 780.09

Postoperative Pain
338.12, 338.18

Other Diseases and Symptoms of the Nervous System
336.1, 436, 780.2, 780.4, 780.97

DIGESTIVE SYSTEM

Ischemic Bowel and Vascular Insufficiency of the Intestine
557.0, 557.9

Intestinal Obstruction and Ileus
560.81, 560.89, 560.9

Ulceration, Bleeding and Perforation of the Digestive System
528.00, 528.02, 528.09, 530.10, 530.12, 530.20, 530.21, 530.82, 531.00, 531.01, 531.10, 531.11, 531.20, 531.21, 531.30, 531.31, 531.40, 531.41, 531.50, 531.51, 531.60, 531.61, 531.70, 531.71, 531.90, 531.91, 532.00, 532.01, 532.10, 532.11, 532.20, 532.21, 532.30, 532.31, 532.40, 532.41, 532.50, 532.51, 532.60, 532.61, 532.70, 532.71, 532.90, 532.91, 533.00, 533.01, 533.10, 533.11, 533.20, 533.21, 533.30, 533.31, 533.40, 533.41, 533.50, 533.51, 533.60, 533.61, 533.70, 533.71, 533.90, 533.91, 534.00, 534.01, 534.10, 534.11, 534.20, 534.21, 534.30, 534.31, 534.40, 534.41, 534.50, 534.51, 534.60, 534.61, 534.70, 534.71, 534.90, 534.91, 535.00, 535.01, 535.40, 535.41, 535.50, 535.51, 535.60, 535.61, 569.3, 569.82, 569.83, 578.9

Acute Liver Failure
570, 572.2

Other Diseases and Symptoms of the Digestive System
560.30, 560.32, 560.39, 568.81, 577.0, 578.0, 578.1

URINARY SYSTEM

Acute Glomerulonephritis and Pyelonephritis
580.0, 580.4, 580.89, 580.9, 590.10, 590.11, 590.80

Nephrotic Syndrome
581.0, 581.1, 581.2, 581.3, 581.89, 581.9

Acute Renal Failure
584.5, 584.6, 584.7, 584.8, 584.9

Other Diseases and Symptoms of the Urinary System
593.9, 599.70, 599.71, 599.72, 788.20, 788.29

COMPLICATIONS OF SURGICAL AND MEDICAL CARE

Mechanical Complication of Cardiac Device, Implant and Graft
Mechanical Complication of Cardiac Pacemaker and AICD
996.00, 996.01, 996.04

APPENDIX B: REASONS FOR READMISSIONS DEFINITIONS *(CONTINUED)*

Mechanical Complication of Heart Valve Prosthesis
996.02

Mechanical Complication of Coronary Artery Bypass Graft
996.03

Other and Unspecified Mechanical Complication
996.09, 996.1

Other Complication of Internal Prosthetic Device, Implant and Graft
Other Complication of Heart Valve Prosthesis
996.71

Other Complication of Other Cardiac Device, Implant and Graft
996.72

Other Complicaton of Vascular Device, Implant and Graft
996.74

Shock
Postoperative Shock
998.0[1], 998.00[2], 998.01[2], 998.02[2], 998.09[2]

Cardiogenic Shock
785.51

Other Shock
785.50, 785.59

Hemorrhage and Hematoma Complicating a Procedure
459.0, 998.11, 998.12, 998.13

Foreign Body Accidentally Left or Accidental Laceration During a Procedure
998.2, 998.4, 998.7

Dehiscence and Rupture of Operation Wound
998.31, 998.32, 998.6, 998.83

Other Complications of Surgical and Medical Care
Nervous System Complication
997.00, 997.01, 997.09

Circulatory System Complication
997.1, 997.2, 997.71, 997.72, 997.79, 999.1, 999.2

Respiratory System Complication
519.00, 519.02, 519.09, 997.39

Digestive System Complication
536.40, 536.42, 536.49, 997.4[1], 997.49[2]

Urinary System Complication
997.5

Other Complications
998.89, 998.9, 999.60, 999.61, 999.62, 999.63, 999.69, 999.70, 999.71, 999.72, 999.73, 999.74, 999.75, 999.76, 999.77, 999.78, 999.79, 999.80, 999.82, 999.83, 999.84, 999.85, 999.88, 999.89

INFECTIONS

Postoperative Infections
997.31, 998.51, 998.59, 999.31, 999.32[2], 999.33[2], 999.34[2], 999.39

Sepsis and Bacteremia
038.0, 038.10, 038.11, 038.12, 038.19, 038.2, 038.3, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 038.8, 038.9, 785.52, 790.7, 995.90, 995.91, 995.92

Pneumonia
Pneumonia
481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.42, 482.49, 482.81, 482.82, 482.83, 482.84, 482.89, 482.9, 485, 486, 511.1

Aspiration Pneumonia
507.0, 997.32[2]

Empyema and Abscess of Lung
510.0, 510.9, 513.0, 513.1

Infection due to Device, Implant and Graft
Cardiac Device, Implant and Graft
996.61

Vascular Device, Implant and Graft
996.62

APPENDIX B: REASONS FOR READMISSIONS DEFINITIONS *(CONTINUED)*

Other and Unspecified Infections due to Device, Implant and Graft
519.01, 536.41

Urinary Tract Infection
590.3, 590.9, 595.0, 599.0, 996.64

Cellulitis
681.00, 681.01, 681.02, 681.10, 681.11, 681.9, 682.0, 682.1, 682.2, 682.3, 682.4, 682.5, 682.6, 682.7, 682.8, 682.9

Osteomyelitis
730.03, 730.06, 730.07, 730.08, 730.09

Intestinal Infection due to Clostridium difficile
008.45

Other Infection Related Conditions and Symptoms
567.21, 567.29, 567.9, 590.2, 780.60, 780.61, 780.62, 780.66

FLUID AND ELECTROLYTE IMBALANCE

Hyperosmolality and Hyposmolality
276.0, 276.1

Acidosis and Alkalosis
276.2, 276.3, 276.4

Dehydration and Hypovolemia
276.50, 276.51, 276.52

Fluid Overload
276.61, 276.69

Hyperpotassemia and Hypopotassemia
276.7, 276.8

Other Electrolyte and Fluid Disorders
276.9

ANEMIA AND COAGULATION DEFECTS

Anemia

Acute Posthemorrhagic Anemia
285.1

Anemia
280.0, 285.9

Coagulation Defects

Hemorrhagic Disorders due to Anticoagulants
286.5[1]

Thrombocytopenia
287.41, 287.49, 287.5, 289.84, 446.6

Other Coagulation Defects
286.6, 286.9, 289.82, 790.92

[1] Invalid as of Oct 1, 2011
[2] Valid as of Oct 1, 2011

APPENDIX C: DEFINITIONS FOR ICD-9-CM CODE-BASED POTENTIAL RISK FACTORS

TABLE C1: ALL PROCEDURE GROUPS

Potential Risk Factor	ICD-9-CM Codes
Acute Myocardial Infarction (AMI) – Initial Episode of Care	Principal diagnosis (pdx) – 410.01, 410.11, 410.21, 410.31, 410.41, 410.51, 410.61, 410.71, 410.81, 410.91
Acute Myocardial Infarction (AMI) – Subsequent Episode of Care	410.02, 410.12, 410.22, 410.32, 410.42, 410.52, 410.62, 410.72, 410.82, 410.92
Alcohol-Related Disorders	291.0, 291.1, 291.2, 291.3, 291.5, 291.81, 291.82, 291.89, 291.9, 303.00, 303.01, 303.02, 303.90, 303.91, 303.92, 305.00, 305.01, 305.02
Anemia	280.1, 280.8, 280.9, 281.0, 281.1, 281.2, 281.3, 281.4, 281.8, 281.9, 282.0, 282.1, 282.2, 282.3, 282.40, 282.41, 282.42, 282.43, 282.44, 282.45, 282.46, 282.47, 282.49, 282.5, 282.60, 282.61, 282.62, 282.63, 282.64, 282.68, 282.69, 282.7, 282.8, 282.9, 283.0, 283.10, 283.11, 283.19, 283.2, 283.9, 284.01, 284.09, 284.1*, 284.11, 284.12, 284.19, 284.2, 284.81, 284.89, 284.9, 285.0, 285.21, 285.22, 285.29, 285.3, 285.8
Angina	413.0, 413.1, 413.9
Angina, Unstable	411.1
Cancer	140.0-209.36, 209.70-209.79, 230.0-239.9
Cancer of the Respiratory System and Intrathoracic Organs	162.0, 162.2, 162.3, 162.4, 162.5, 162.8, 162.9, 163.0, 163.1, 163.8, 163.9, 164.0, 164.1, 164.2, 164.3, 164.8, 164.9, 165.0, 165.8, 165.9, 170.3, 171.4, 196.1, 197.0, 197.1, 197.2, 197.3, 200.00, 200.01, 200.02, 200.12, 200.22, 200.32, 200.42, 200.52, 200.62, 200.72, 200.82, 201.02, 201.12, 201.22, 201.42, 201.52, 201.62, 201.72, 201.92, 202.02, 202.12, 202.22, 202.32, 202.42, 202.52, 202.62, 202.72, 202.82, 202.92, 209.21, 209.22, 231.0, 231.1, 231.2, 231.8, 231.9, 235.6, 235.7, 235.8, 235.9
Cardiac Adhesions	423.1, 519.3
Cardiac Assist Device Prior to First CABG/Valve Surgery Date	37.60, 37.62, 37.65, 37.66, 37.68
Cardiomyopathy	425.1*, 425.11, 425.18, 425.3, 425.4, 425.5, 425.8, 425.9, 429.3
Cardiopulmonary Resuscitation (CPR) Prior to First CABG/Valve Surgery Date	93.93, 99.60, 99.62, 99.63
Cerebrovascular Disease	433.00, 433.10, 433.20, 433.30, 433.80, 433.90, 434.00, 434.10, 434.90, 437.0, 437.1, 437.3, 437.4, 442.81, 446.5
Chronic Kidney Disease	403.00, 403.01, 403.10, 403.11, 403.90, 403.91, 404.00, 404.02, 404.10, 404.12, 404.90, 404.92, 585.1, 585.2, 585.3, 585.4, 585.5, 585.6, 585.9
Chronic Lung Disease	491.0, 491.1, 491.20, 491.21, 491.22, 492.0, 492.8, 493.20, 493.21, 493.22, 494.0, 494.1, 496, 500, 501, 502, 503, 504, 505, 506.4, 508.1, 515, 518.2, 518.83
Chronic Pulmonary Hypertension	416.0, 416.1, 416.2, 416.8, 416.9
Coagulopathy	286.0, 286.1, 286.2, 286.3, 286.4, 287.30, 287.31, 287.32, 287.33, 287.39, 289.81
Congenital Heart Anomalies	745.0, 745.10, 745.11, 745.12, 745.19, 745.2, 745.3, 745.4, 745.5, 745.60, 745.61, 745.69, 745.7, 745.8, 745.9, 746.01, 746.02, 746.09, 746.1, 746.2, 746.3, 746.4, 746.5, 746.6, 746.7, 746.81, 746.82, 746.83, 746.84, 746.85, 746.86, 746.87, 746.89, 746.9, 747.0, 747.10, 747.11, 747.20, 747.21, 747.22, 747.29, 747.3*, 747.31, 747.32, 747.39, 747.40, 747.41, 747.42, 747.49
Dental Extraction Prior to First CABG/Valve Surgery Date	23.09, 23.19

APPENDIX C: DEFINITIONS FOR ICD-9-CM CODE-BASED POTENTIAL RISK FACTORS *(CONTINUED)*

Potential Risk Factor	ICD-9-CM Codes
TABLE C1: ALL PROCEDURE GROUPS *CONTINUED*	
Diabetes	249.00, 249.01, 249.10, 249.11, 249.20, 249.21, 249.30, 249.31, 249.40, 249.41, 249.50, 249.51, 249.60, 249.61, 249.70, 249.71, 249.80, 249.81, 249.90, 249.91, 250.00, 250.01, 250.02, 250.03, 250.10, 250.11, 250.12, 250.13, 250.20, 250.21, 250.22, 250.23, 250.30, 250.31, 250.32, 250.33, 250.40, 250.41, 250.42, 250.43, 250.50, 250.51, 250.52, 250.53, 250.60, 250.61, 250.62, 250.63, 250.70, 250.71, 250.72, 250.73, 250.80, 250.81, 250.82, 250.83, 250.90, 250.91, 250.92, 250.93
Extracorporeal Membrane Oxygenation (ECMO) Prior to First CABG/Valve Surgery Date	39.65
Gastroparesis	536.3
Heart Failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, 428.9
History of CABG or Valve Surgery	414.02, 414.03, 414.04, 414.05, V13.65, V42.2, V43.3, V45.81 pdx for the following: 996.02, 996.03, 996.61, 996.71, 996.72
History of Cancer	V10.00, V10.01, V10.02, V10.03, V10.04, V10.05, V10.06, V10.07, V10.09, V10.11, V10.12, V10.20, V10.21, V10.22, V10.29, V10.3, V10.40, V10.41, V10.42, V10.43, V10.44, V10.45, V10.46, V10.47, V10.48, V10.49, V10.50, V10.51, V10.52, V10.53, V10.59, V10.60, V10.61, V10.62, V10.63, V10.69, V10.71, V10.72, V10.79, V10.81, V10.82, V10.83, V10.84, V10.85, V10.86, V10.87, V10.88, V10.89, V10.90, V10.91
History of Chronic Steroid Use	V58.65, V87.44, V87.45, V87.46
History of Lower Extremity Amputation	V49.70, V49.71, V49.72, V49.73, V49.74, V49.75, V49.76, V49.77
History of Pacemaker or Defibrillator	V45.01, V45.02, V45.03, V53.31, V53.32, V53.39
History of Peripheral Vascular Disease	440.0, 440.1, 440.20, 440.21, 440.22, 440.23, 440.24, 440.29, 440.30, 440.31, 440.32, 440.4, 440.8, 440.9, 441.2, 441.4, 441.7, 441.9, 442.0, 442.1, 442.2, 442.3, 442.82, 442.83, 442.84, 443.0, 443.1, 443.81, 443.82, 443.89, 443.9, 447.70, 447.71, 447.72, 447.73, 453.50, 453.51, 453.52, 453.71, 453.72, 453.73, 453.74, 453.75, 453.76, 453.77, 453.79, 454.0, 454.1, 454.2, 454.8, 454.9, 459.30, 459.31, 459.32, 459.33, 459.39, 459.81, 557.1, 593.81
History of PTCA/Stent	V45.82
History of Stroke	438.0, 438.10, 438.11, 438.12, 438.13, 438.14, 438.19, 438.20, 438.21, 438.22, 438.30, 438.31, 438.32, 438.40, 438.41, 438.42, 438.50, 438.51, 438.52, 438.53, 438.6, 438.7, 438.81, 438.82, 438.83, 438.84, 438.85, 438.89, 438.9, V12.54
History of Thrombosis or Embolism	V12.51, V12.55
Hypercholesterolemia	272.0, 272.1, 272.2, 272.3, 272.4
Hypertension	401.0, 401.1, 401.9, 402.00, 402.10, 402.90, 405.01, 405.09, 405.11, 405.19, 405.91, 405.99
Illegal Drug-Related Disorders	292.0, 292.11, 292.12, 292.2, 292.81, 292.82, 292.83, 292.84, 292.85, 292.89, 292.9, 304.00, 304.01, 304.02, 304.10, 304.11, 304.12, 304.20, 304.21, 304.22, 304.30, 304.31, 304.32, 304.40, 304.41, 304.42, 304.50, 304.51, 304.52, 304.60, 304.61, 304.62, 304.70, 304.71, 304.72, 304.80, 304.81, 304.82, 304.90, 304.91, 304.92, 305.20, 305.21, 305.22, 305.30, 305.31, 305.32, 305.40, 305.41, 305.42, 305.50, 305.51, 305.52, 305.60, 305.61, 305.62, 305.70, 305.71, 305.72, 305.80, 305.81, 305.82, 305.90, 305.91, 305.92
Intra-Aortic Balloon Pump (IABP) Prior to First CABG/Valve Surgery Date	37.61
Ischemic Heart Disease	414.8, 414.9, 429.0, 429.1
Liver Disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.70, 070.71, 456.0, 456.1, 456.20, 456.21, 571.0, 571.1, 571.2, 571.3, 571.40, 571.41, 571.42, 571.49, 571.5, 571.6, 571.8, 571.9, 572.3, 572.4, 572.8, 573.0, 573.1, 573.2, 573.3, 573.5

APPENDIX C: DEFINITIONS FOR ICD-9-CM CODE-BASED POTENTIAL RISK FACTORS *(CONTINUED)*

Potential Risk Factor	ICD-9-CM Codes
TABLE C1: ALL PROCEDURE GROUPS *CONTINUED*	
Long-term Use of Anticoagulants and Antiplatelets	V58.61, V58.63
Long-term Use of Insulin	V58.67
Lupus Erythematosus, Systemic	710.0
Malnutrition	261, 262, 263.0, 263.1, 263.2, 263.8, 263.9, 799.4, V85.0
Mental Disorders	295.00-295.95, 296.00-296.99, 297.0, 297.1, 297.2, 297.3, 297.8, 297.9, 298.0, 298.1, 298.4, 298.8, 298.9, 299.00, 299.01, 299.10, 299.11, 299.80, 299.81, 299.90, 299.91, 300.00, 300.01, 300.02, 300.09, 300.10, 300.11, 300.12, 300.13, 300.14, 300.15, 300.16, 300.19, 300.20, 300.21, 300.22, 300.23, 300.29, 300.3, 300.4, 300.5, 300.6, 300.7, 300.81, 300.82, 300.89, 300.9, 301.0, 301.10, 301.11, 301.12, 301.13, 301.20, 301.21, 301.22, 301.3, 301.4, 309.1, 311, 317, 318.0, 318.1, 318.2, 319, 331.0, 332.0
Myocardial Infarction, Old	412
Non-Invasive Mechanical Ventilation (NIMV) Prior to First CABG/Valve Surgery Date	93.90
Morbid Obesity	278.01, V85.39, V85.41, V85.42, V85.43, V85.44, V85.45
Obesity	278.00, 278.01, V85.30, V85.31, V85.32, V85.33, V85.34, V85.35, V85.36, V85.37, V85.38, V85.39, V85.41, V85.42, V85.43, V85.44, V85.45
Obstructive Sleep Apnea and Obesity-Related Hypoventilation Syndrome	278.03, 327.23
Osteoporosis	733.00, 733.01, 733.02, 733.03, 733.09
Other Open Heart Procedure Same Day as First CABG/Valve Surgery	35.00, 35.01, 35.02, 35.03, 35.04, 35.31, 35.32, 35.34, 35.35, 35.39, 35.71, 35.95, 35.98, 36.2, 36.31, 36.32, 36.39, 36.91, 36.99, 37.10, 37.11, 37.12, 37.31, 37.41, 37.49, 37.51, 37.52, 37.53
Oxygen Therapy Dependence (long-term)	V46.11, V46.2
Percutaneous Valve Procedures Prior to First CABG/Valve Surgery Date	35.05, 35.06, 35.07, 35.08, 35.09, 35.96, 35.97
Percutaneous Valve Procedures Same Day as First CABG/Valve Surgery	35.05, 35.06, 35.07, 35.08, 35.09, 35.96, 35.97
Preoperative Acute Renal Failure	584.5, 584.6, 584.7, 584.8, 584.9 plus confirmation of acute renal failure prior to *first* CABG and/or valve surgery based on review of medical record documentation.
Preoperative Cardiogenic Shock	785.51 plus confirmation of cardiogenic shock prior to *first* CABG and/or valve surgery based on review of medical record documentation.
PTCA/Stent Prior to First CABG/Valve Surgery Date	00.66, 17.55, 36.06, 36.07, 36.09
PTCA/Stent Same Day as First CABG/Valve Surgery	00.66, 17.55, 36.06, 36.07, 36.09

[1] Invalid as of October 1, 2011

TABLE C2: CABG WITHOUT VALVE PROCEDURE GROUP

Potential Risk Factor	ICD-9-CM CODES
Heart Valve Disease	394.0, 394.1, 394.2, 394.9, 395.0, 395.1, 395.2, 395.9, 396.0, 396.1, 396.2, 396.3, 396.8, 396.9, 397.0, 397.1, 424.0, 424.1, 424.2, 424.3

APPENDIX C: DEFINITIONS FOR ICD-9-CM CODE-BASED POTENTIAL RISK FACTORS *(CONTINUED)*

TABLE C3: VALVE WITHOUT CABG PROCEDURE GROUP

Potential Risk Factor	ICD-9-CM CODES
Coronary Artery Disease	414.00, 414.01
Excision of Left Atrial Appendage (LAA) Same Day as First CABG/Valve Surgery	37.36
Excision of Other Lesion Same Day as First CABG/Valve Surgery	37.33, 37.37
Multiple Valve Procedures Same Day as First CABG/Valve Surgery	Any combination of valve procedure codes (i.e., replacements and/or repairs): 35.10, 35.11, 35.12, 35.13, 35.14, 35.20, 35.21, 35.22, 35.23, 35.24, 35.25, 35.26, 35.27, 35.28, 35.33, 35.99
Heart Valve Disease (Rheumatic) (only codes for rheumatic heart valve disease apply to valve cases)	394.0, 394.1, 394.2, 394.9, 395.0, 395.1, 395.2, 395.9, 396.0, 396.1, 396.2, 396.3, 396.8, 396.9, 397.0, 397.1
Type of Valve Procedure – Annuloplasty, Same Day as First CABG/Valve Surgery	35.33
Type of Valve Procedure – Aortic, Same Day as First CABG/Valve Surgery	35.11, 35.21, 35.22
Type of Valve Procedure – Mitral, Same Day as First CABG/Valve Surgery	35.12, 35.23, 35.24
Type of Valve Procedure – Pulmonary, Same Day as First CABG/Valve Surgery	35.13, 35.25, 35.26
Type of Valve Procedure – Tricuspid, Same Day as First CABG/Valve Surgery	35.14, 35.27, 35.28
Valve Replacement Same Day as First CABG/Valve Surgery	35.21, 35.22, 35.23, 35.24, 35.25, 35.26, 35.27, 35.28

TABLE C4: VALVE WITH CABG PROCEDURE GROUP

Potential Risk Factor	ICD-9-CM CODES
Excision of Left Atrial Appendage (LAA) Same Day as First CABG/Valve Surgery	37.36
Excision of Other Lesion Same Day as First CABG/Valve Surgery	37.33, 37.37
Multiple Valve Procedures Same Day as First CABG/Valve Surgery	Any combination of valve procedure codes (i.e., replacements and/or repairs): 35.10, 35.11, 35.12, 35.13, 35.14, 35.20, 35.21, 35.22, 35.23, 35.24, 35.25, 35.26, 35.27, 35.28, 35.33, 35.99
Heart Valve Disease (Rheumatic) (only codes for rheumatic heart valve disease apply to valve cases)	394.0, 394.1, 394.2, 394.9, 395.0, 395.1, 395.2, 395.9, 396.0, 396.1, 396.2, 396.3, 396.8, 396.9, 397.0, 397.1
Type of Valve Procedure – Annuloplasty, Same Day as First CABG/Valve Surgery	35.33
Type of Valve Procedure – Aortic, Same Day as First CABG/Valve Surgery	35.11, 35.21, 35.22
Type of Valve Procedure – Mitral, Same Day as First CABG/Valve Surgery	35.12, 35.23, 35.24
Type of Valve Procedure – Pulmonary, Same Day as First CABG/Valve Surgery	35.13, 35.25, 35.26
Type of Valve Procedure – Tricuspid, Same Day as First CABG/Valve Surgery	35.14, 35.27, 35.28
Valve Replacement Same Day as First CABG/Valve Surgery	35.21, 35.22, 35.23, 35.24, 35.25, 35.26, 35.27, 35.28

APPENDIX D: EXAMPLE OF LOGISTIC REGRESSION AND CALCULATING STATISTICAL RATINGS

Total Cases: Number of hospitalizations after exclusions.

Actual Deaths: Total number of deaths (death is a discharge status equal to 20).

Rate: Total number of deaths / Total number of cases.

Expected Deaths: Sum of each patient's probability of death (PD).

Rate: Sum of each patient's probability of death (PD) / Total number of cases.

To calculate a patient's probability of death:

Step 1: Calculate βX:

βX = -6.1001 + 0.9009 (Valve with CABG) + 0.0006 (Age) +. . . + 1.2334 (Preoperative Cardiogenic Shock) + . . . + 1.5315 (Liver Disease) + coefficient (other variables in in-hospital mortality model) . . .

Step 2: Calculate the estimated probability of death (PD) using βX:

$PD = e^{\beta X} / (1 + e^{\beta X})$ where $e \approx 2.7182818285$

Test Statistic: z = (Actual Deaths – Expected Deaths) / Standard Deviation of Mortality

To compute Standard Deviation of Mortality:

Step 1: Compute the estimated variance of each patient's probability of death (VARPAT):

VARPAT = (PD) (1-PD)

Step 2: Calculate the Standard Deviation of Mortality

SUMVAR = sum of VARPAT across all cases

Standard Deviation of Mortality = square root of SUMVAR

p-value (two sided): Calculated using test statistic as a normal z-score

Statistical Rating: If p-value <0.05 and test statistic >0, then more deaths than expected (denoted as "●")
If p-value <0.05 and test statistic <0, then fewer deaths than expected (denoted as "○")
Otherwise, the number of deaths were within the expected range (denoted as "⊙")

Expected Range: Lower limit = Expected Deaths – 1.960 (Standard Deviation of Mortality)
Upper limit = Expected Deaths + 1.960 (Standard Deviation of Mortality)

APPENDIX E: EXAMPLE OF CASE-MIX ADJUSTMENT

Region 1: Southwestern PA
Procedure Group: Valve without CABG

Total Cases: Number of hospitalizations for a hospital after exclusions (equal to n).

Actual Charge: Average actual charges for a hospital (Average ActChg).

Expected Charge: Average expected charges for a hospital (Average ExpChg).

Step 1: Calculate each hospitalization's expected charge (ExpChg):

ExpChg = the expected charge for a hospitalization, which is equal to the average charge for all hospitalizations (after exclusion) in the hospital's same region and MS-DRG group within the procedure group.

Region 1 - Southwestern PA, valve without CABG, MS-DRG Group 5: $217,167
or
Region 1 - Southwestern PA, valve without CABG, MS-DRG Group 6: $164,137

Step 2: Calculate the average ExpChg for a hospital (expected charge):

$$\text{Average ExpChg} = \frac{\Sigma \text{ ExpChg}}{n}$$

Case-Mix Adjusted Charge: $\frac{\text{Average ActChg}}{\text{Average ExpChg}}$ (Region 1 Average Actual Charge)