Technical Notes

for

PHC4's Report on CABG and Valve Surgery

Calendar Year 2005

The Pennsylvania Health Care Cost Containment Council
April 2007

Preface

This document serves as a technical supplement to PHC4's report on coronary artery bypass graft (CABG) and valve surgery for calendar year 2005 (January 1, 2005 to December 31, 2005). The *Technical Notes for PHC4's Report on CABG and Valve Surgery* describes the methodology and development of the report. This document also includes information on statewide results, cases excluded from analysis, and risk-adjustment models.

- For the first time, this report presents data on the outcomes associated with heart valve surgery in addition to data on CABG surgery.
- Commercial insurance payment data and Medicare payment data are also reported at the hospital level for the first time.
- The analysis included adult patients at least 30 years of age who underwent a CABG procedure, a valve procedure, or combined valve and CABG procedures in a Pennsylvania general acute care hospital.
- Risk-adjusted measures for hospitals and surgeons with at least 30 cases are reported for:
    - *In-hospital mortality*
    - *Operative mortality (includes in-hospital and 30-day)*
    - *7-day readmissions*
    - *30-day readmissions*
    - *Post-surgical length of stay*
- The following measures are reported for hospitals with at least 5 cases:
    - *Average hospital charge (case-mix adjusted)*
    - *Average commercial insurance payment*
- Currently, the following measure is reported for hospitals with at least 13 cases:
    - *Average Medicare payment*

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.

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DATA COLLECTION AND VERIFICATION

The Pennsylvania Health Care Cost Containment Council (PHC4) is mandated by state law to collect and disseminate health care data. The data for PHC4's 2005 report on CABG and valve surgery were submitted electronically on a quarterly basis to PHC4 by Pennsylvania general acute care (GAC) hospitals as directed by the data submission requirements of Act 89 of 1986 (currently Act 14 of 2003). The data submitted by hospitals included demographic information, hospital charges, and diagnosis and procedure codes. Facilities were required to submit data to PHC4 within 90 days from the last day of each quarter. The standard data verification process included extensive quality assurance and data quality checks. Error reports were generated and returned to each facility with an opportunity to correct any problems.

In addition, hospitals were required to use the MediQual *Atlas Outcomes*® System to abstract information from the medical record that described each patient's state of health on admission.

Commercial and Medicare payment data were obtained directly from the payors. Commercial payment data were received from commercial payors, and Medicare payment data were provided by the Centers for Medicare and Medicaid Services (CMS).

Death certificate data were obtained from the Pennsylvania Department of Health to identify deaths that occurred subsequent to the hospitalization in which the CABG/valve surgery was performed.

Hospital and Cardiothoracic Surgeon Verification of Data

Discharge records for patients who underwent an open heart procedure in 2005 were subjected to extensive data verification and quality assurance checks. Hospitals were requested to confirm the accuracy of discharge records, provide six additional diagnoses and three additional procedure codes as appropriate, and confirm that cases had the correct surgeon assignment. Surgeons were requested 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 surgery and not accounted for through risk adjustment. In addition, hospitals and/or surgeons had the opportunity to identify cases in which cardiogenic shock and/or acute renal failure were present at or immediately prior to the surgery, because of their importance as risk factors. Medical records were reviewed to verify the presence of these risk factors and to determine whether special requests for exclusion would be granted.

STUDY POPULATION

The CABG and valve study population included those patients discharged from Pennsylvania general acute care hospitals in calendar year 2005 after undergoing CABG and/or valve surgery as identified by the presence of an appropriate ICD-9-CM procedure code(s) in either the principal or secondary procedure position of the discharge record. The population included three subgroups of patients as defined below.

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

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.

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	Replacement of unspecified heart valve
35.21	Replacement of aortic valve with tissue graft
35.22	Other replacement of aortic valve
35.23	Replacement of mitral valve with tissue graft
35.24	Other replacement of mitral valve
35.25	Replacement of pulmonary valve with tissue graft
35.26	Other replacement of pulmonary valve
35.27	Replacement of tricuspid valve with tissue graft
35.28	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*** at least one of the above CABG procedures during the same admission.

EXCLUSIONS FOR OUTCOME ANALYSES

Cases meeting certain criteria were excluded from the outcome analyses. Standard exclusions consisted of the following: 1) clinically complex cases, 2) patients less than 30 years of age, and 3) patients who left against medical advice. Standard exclusion criteria were applied to the in-hospital mortality analysis. Standard exclusion *and* exclusion criteria particular to the measure of interest were applied to the analyses of operative mortality, 7-day and 30-day readmissions, post-surgical length of stay, and average hospital charge. Appendix B displays exclusion data for each outcome measure.

MEASURES REPORTED

Number of Cases

The number of cases (after standard exclusions were removed) is reported for hospitals and surgeons. The number of cases is displayed for each of the following reporting groups:

- ***CABG without Valve*** is the number of patients who underwent at least one CABG procedure without any valve procedures during the same admission.
- ***Valve without CABG*** is the number of patients who underwent at least one valve procedure without any CABG procedures during the same admission.
- ***Valve with CABG*** is the number of patients who underwent at least one valve procedure and at least one CABG procedure during the same admission.
- ***Total Valve*** is the total number of patients who underwent at least one valve procedure with or without a CABG procedure during the same admission.

Note that the actual number of CABG/valve surgeries performed by a particular surgeon may be underreported. For example, procedures done in Veterans' hospitals and in other states were not included in this analysis.

In-Hospital Mortality

The in-hospital mortality rating was based on the number of deaths that occurred during the hospital admission in which the CABG/valve surgery was performed compared to the expected number of deaths. Information on whether the patient died during the hospital stay was provided by hospitals.

Operative Mortality

The operative mortality rating was based on the total number of operative deaths compared to the expected number of deaths. Operative deaths were defined as:

- The number of deaths that occurred during the hospitalization in which the CABG/valve surgery was performed, even if after 30 days, *and*
- The number of deaths that occurred after the patient was discharged from the hospital, but within 30 days of the procedure, unless the death was clearly

unrelated to the procedure (e.g., drug/alcohol poisoning). To determine whether a patient died within 30 days, death certificate information was obtained from the Pennsylvania Department of Health. Out-of-state residents were excluded from the analysis, because death certificate information was not available for these patients.

7-Day Readmissions

Some patients discharged from the hospital following CABG/valve surgery were readmitted at a later date. The 7-day readmissions rating was based on the number of patients who were readmitted to a general acute care hospital (in Pennsylvania) within 1 to 7 days of being discharged from the hospitalization in which the CABG/valve surgery was performed compared to the expected number of readmissions. Readmissions were counted when the principal diagnosis indicated a heart-related condition, an infection, and/or a complication related to the surgery. Appendix C contains a list of diagnosis categories for which there was one or more readmissions.

30-Day Readmissions

Similar to 7-day readmissions, the 30-day readmission rating was based on the number of patients who were readmitted to a general acute care hospital within 1 to 30 days of being discharged from the hospitalization in which the CABG/valve surgery was performed compared to the expected number of readmissions. Readmissions were counted using the same principal diagnosis criteria used for 7-day readmissions. Appendix C contains a list of diagnosis categories for which there was one or more readmissions.

Post-Surgical Length of Stay

Post-surgical length of stay is the risk-adjusted number of days, on average, that patients stayed in the hospital following CABG/valve surgery.

Average Hospital Charge

Average hospital charge is reported for hospitals that had at least 5 cases in the reporting group of interest. The average charges that appear in the report were trimmed for outliers and case-mix adjusted. The charges reported are those associated with the entire hospitalization during which the CABG/valve surgery was performed (not just the treatment associated with surgery). The charges do not include professional fees (e.g., physician fees). While charges are a standard way of reporting data, they do not reflect the actual cost of treatment, nor do they reflect the payment that the hospital may have actually received.

Average Commercial Payment

The average commercial payment is reported for hospitals that had at least 5 cases in the reporting group of interest for which commercial payment data was available. Average payments were not trimmed for outliers and not case-mix adjusted; that is, actual average commercial payments are reported.

Average Medicare Payment

Currently, the average Medicare payment is reported for hospitals that had at least 13 cases in the reporting group of interest for which Medicare payment data was available. Average payments were not trimmed for outliers and not case-mix adjusted; that is, actual average Medicare payments are reported.

RISK-ADJUSTMENT

In-hospital mortality, operative mortality, 7-day readmissions, 30-day readmissions, and post-surgical length of stay were risk-adjusted, which means that the measure took into account the patient's health condition before surgery. Some patients who underwent CABG/valve surgery were more seriously ill than others. In order to report fair comparisons among hospitals and surgeons, PHC4 developed a complex mathematical formula to "risk adjust" the data, meaning that hospitals and surgeons receive "extra credit" for operating on patients that were more seriously ill or at a greater risk than others. Risk adjusting the data was important because sicker patients might be more likely to die, stay in the hospital longer, or be readmitted. Through logistic or linear regression modeling, risk factors (e.g., the age and sex of the patient and factors that indicate the illness level of the patient) were "tested" to determine which factors predicted patient outcomes (i.e., in-hospital mortality, operative mortality, 7-day and 30-day readmissions, and post-surgical length of stay). Note that a separate risk-adjustment model was built for each of these outcome measures. The risk-adjustment models were then used to calculate the risk-adjusted ratings displayed in the report.

Each hospital and surgeon with at least 30 cases in a particular procedure group (after exclusions) received ratings for in-hospital mortality, operative mortality, 7-day readmissions, and 30-day readmissions. The ratings indicate whether the hospital or the surgeon's mortality or readmissions rate was within the expected range or higher or lower than expected, taking into account the risk factors that were included in the risk-adjustment models. Rather than reporting a statistical rating for post-surgical length of stay, the risk-adjusted length of stay is reported in days. Additional detail on the methodology used to build the models and compute statistical ratings can be found in the sections titled "Risk-Adjustment Methodology."

MORTALITY AND READMISSIONS ANALYSES

Risk-Adjustment Methodology

Data Preparation

After cases to be excluded from the analyses were removed, the remaining cases were randomly split into two equal-size samples by procedure group (CABG without valve, valve without CABG, and valve with CABG)—a development sample and a cross-validation sample. The number of relevant cases for each sample is shown in Table 1.

Table 1. Frequencies for Development Sample, Cross-Validation Sample, and Full Data Set

	Development Sample	Cross-Validation Sample	Full Data Set
In-hospital mortality			
Number of cases	8,666	8,665	17,331
Number of in-hospital deaths	254	253	507
Mortality rate (%)	2.9	2.9	2.9
Operative mortality			
Number of cases	7,873	7,871	15,744
Number of operative deaths	272	274	546
Mortality rate (%)	3.5	3.5	3.5
7-day readmissions			
Number of cases	7,650	7,647	15,297
Number of readmissions within 7 days	437	481	918
Readmissions rate (%)	5.7	6.3	6.0
30-day readmissions			
Number of cases	7,650	7,647	15,297
Number of readmissions within 30 days	1,139	1,160	2,299
Readmissions rate (%)	14.9	15.2	15.0

Building the Risk-Adjustment Models

Identifying possible risk factors. The first step in building the risk-adjustment models for in-hospital mortality, operative mortality, 7-day readmissions, and 30-day readmissions was to identify possible risk factors, that is, those factors that potentially contributed to these events. In doing so, both clinical and demographic factors identified in the literature were considered, taking into account the availability and usability of the variables in the database. Also considered were factors tested in previous cardiac-related reports released by the Council and MediQual's Key Clinical Findings (KCFs; see Appendix F). These possible risk-adjustment factors are called candidate variables. Appendices D and E provide definitions and data for candidate variables that were considered in the present analyses.

Once the candidate variables were identified, models for each outcome measure were developed using the following processes: model selection, cross-validation, and calculation of model adequacy measures.

Model selection for mortality models. Binary logistic regression was used to select risk factors for the in-hospital and operative mortality models. For the mortality models, the variables in Table 2a, which were developed primarily by MediQual for their CABG/valve in-hospital mortality model using the MediQual *Atlas Outcomes*® System data, were entered into the models and retained, unless the analysis did not suggest that the variable would be predictive of the outcome.

Table 2a. Development Models: Candidate Variables Entered Into the Model that were Developed Primarily by MediQual

Demographic Variables	Laboratory Variables
Age in Years	Albumin < 3.1
Age # Years > 65	BUN > 40
Female	Creatinine > 1.4
	Glucose > 165[1]

Clinical Variables Other Than Laboratory Variables	
AMI Other Inferior Wall Initial Episode	History of Peripheral Vascular Disease
ASA Class 5	MI Other Anterior Wall
ASA Emergency Flag	Mild Moderate or Severe AMS
CAD > 70, 5-7 Vessels Grp	Other CV Procedure Group
Current Med Immunosuppressants	Percent of Left Main Stenosis[1]
Current Med Insulin	Procedure Group
Ejection Fraction	PTCA/Stent/Tear Same Day as CABG/Valve Surgery
Heart Failure	Septal Other Anomalous Repair Heart
History of CABG or Valve Surgery	SIRS Group

[1] This variable was not retained in the operative mortality model because the analysis did not suggest that the variable would be predictive of operative mortality.

The variables in Table 2b were entered into the mortality models and tested for their impact in each model. Using a backward stepwise technique, candidate variables that had the least impact in the model were eliminated one at a time, until all variables remaining in the model were statistically significant. All tests of significance ($p < 0.10$) were based on the likelihood ratio. Table 2b notes the tested variables that were found to be significant in the mortality models.

Table 2b. Development Models: Variables Tested as Potential Predictors for Mortality

Candidate Variables	Results for Mortality	
	In-Hospital	Operative
Clinical Variables Other Than Laboratory Variables		
AMI Except Other Anterior or Other Inferior Wall	✓	ns
Cachexia	✓	✓
Cancer	not tested[1]	✓
Cardiogenic Shock, Preoperative	✓	✓
Cardiomyopathy	not tested[1]	ns
Chronic Lung Disease	ns	ns
Chronic Pulmonary Hypertension	ns	ns
Coagulopathy	✓	ns
Excision of Other Lesion/Heart Tissue, Open Approach – Same Date as Valve Surgery w/wo CABG	ns	not tested[1]
Hypertension with Complications	✓	✓
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery	ns	✓
Liver Disease	✓	not tested[1]
Multiple Valve Procedures	ns	✓
Renal Failure/Dialysis (category)	ns	ns

✓ : significant predictor ($p < 0.10$)
ns: not significant
[1] This variable was not tested because the preliminary analysis did not suggest that the variable would be predictive of the relevant outcome.

Model selection for readmissions models. As with the mortality models, binary logistic regression was used to select risk factors for the 7-day readmissions and 30-day readmissions models. Table 2c lists the variables tested in the readmissions models. Note that the variables developed primarily by MediQual competed equally with other potential predictors during the selection process. Using a backward stepwise technique, candidate variables that had the least impact in the model were eliminated one at a time, until all variables remaining in the model were statistically significant. All tests of significance ($p < 0.10$) were based on the likelihood ratio. Table 2c notes the tested variables that were found to be significant in the readmissions models.

Table 2c. Development Models: Variables Tested as Potential Predictors of Readmissions

Candidate Variables	Results for Readmissions	
	7-Day	30-Day
Demographic Variables		
Age in Years	ns	ns
Age # Years > 65	✓	✓
Female	ns	✓
Race	not tested[1]	ns
Clinical Variables Other Than Laboratory Variables		
ASA Class 5	ns	not tested[1]
Chronic Lung Disease	✓	✓
Chronic Pulmonary Hypertension	ns	ns
Diabetes	not tested[1]	✓
Diabetes with Long Term/Unspecified Complications	✓	not tested[1]
Excision of Other Lesion/Heart Tissue, Open Approach – Same Date as Valve Surgery w/wo CABG	ns	ns
Heart Failure	✓	✓
History of Peripheral Vascular Disease	not tested[1]	✓
Hypertension with Complications	ns	ns
Morbid Obesity	not tested[1]	ns
MediQual Predicted Length of Stay	ns	✓
Multiple Valve Procedures	not tested[1]	ns
Other CV Procedure Group	ns	ns
Procedure Group	✓	✓
PTCA/Stent/Tear Same Day as CABG/Valve Surgery	✓	not tested[1]
Renal Failure/Dialysis (category)	not tested[1]	ns
Renal Failure/Dialysis (binary)	ns	not tested[1]

✓ : significant predictor ($p < 0.10$)
ns: not significant
[1] This variable was not tested because the preliminary analysis did not suggest that the variable would be predictive of the relevant outcome.

Cross-validation. After the development models were built for in-hospital mortality, operative mortality, 7-day readmissions, and 30-day readmissions, the models were cross-validated. In order to determine which factors remained significant when the development model was applied to the cross-validation sample, the model built in the model selection process was re-estimated using the cases in the cross-validation sample. Regression analyses were performed to determine whether the selected candidate variables would remain predictive of the relevant outcomes in the cross-validation sample. During the cross-validation process of the mortality models, the variables developed primarily by MediQual were entered in the models but not considered for cross-validation.

Tables 3a and 3b present the probability values (*p*-values) in the development, cross-validation, and full data set models for each of the significant variables. Variables that were not found to be significant during the model selection process (noted with "ns" in Tables 2b and 2c) were not tested during cross-validation. Variables with a *p*-value equal to or greater than 0.10 in the cross-validation model did not "cross validate." For the in-hospital mortality model, preoperative cardiogenic shock, coagulopathy, and liver disease did not cross validate. For the operative mortality model, cancer, preoperative cardiogenic shock, and IABP prior to date of CABG/valve surgery did not cross validate. For the 7-day readmissions model, age # years > 65, diabetes with long term/unspecified complications, procedure group, and PTCA/stent/tear same day as CABG/valve surgery did not cross validate. For 30-day readmissions, heart failure and procedure group did not cross validate. Variables that did not cross validate were still used as risk-adjustment factors in the full dataset model.

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Table 3a. Cross-Validation Results: p-values for Significant Candidate Variables in the Mortality Models

Significant Variables in Development Model	In-Hospital Mortality			Operative Mortality		
	Development Model	Cross-Validation Model	Full Data Set	Development Model	Cross-Validation Model	Full Data Set
Clinical Variables Other Than Laboratory Variables						
AMI Except Other Anterior or Other Inferior Wall	0.073	0.065	0.009	ns	ns	ns
Cachexia	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Cancer	not tested[1]	not tested[1]	not tested[1]	0.047	0.987	0.173
Cardiogenic Shock, Preoperative	0.001	0.132	0.001	0.002	0.247	0.005
Coagulopathy	0.002	0.490	0.008	ns	ns	ns
Hypertension with Complications	0.001	0.025	< 0.001	0.014	< 0.001	< 0.001
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery	ns	ns	ns	0.030	0.156	0.012
Liver Disease	0.037	0.202	0.016	not tested[1]	not tested[1]	not tested[1]
Multiple Valve Procedures	ns	ns	ns	0.089	0.022	0.005

ns: not significant

[1] This variable was not tested because the preliminary analysis did not suggest that the variable would be predictive of the relevant outcome.

Table 3b. Cross-Validation Results: p-values for Significant Candidate Variables in the Readmissions Models

Significant Variables in Development Model	7-Day Readmissions			30-Day Readmissions		
	Development Model	Cross-Validation Model	Full Data Set	Development Model	Cross-Validation Model	Full Data Set
Demographic Variables						
Age # Years > 65	< 0.001	0.103	< 0.001	0.007	0.058	0.001
Female	ns	ns	ns	0.048	0.001	< 0.001
Clinical Variables Other Than Laboratory Variables						
Chronic Lung Disease	< 0.001	0.039	< 0.001	< 0.001	0.076	< 0.001
Diabetes	not tested[1]	not tested[1]	not tested[1]	0.004	< 0.001	< 0.001
Diabetes with Long Term/ Unspecified Complications	< 0.001	0.593	0.006	not tested[1]	not tested[1]	not tested[1]
Heart Failure	0.026	< 0.001	< 0.001	0.087	0.598	0.103
History of Peripheral Vascular Disease	not tested[1]	not tested[1]	not tested[1]	0.041	0.005	0.001
MediQual Predicted Length of Stay	ns	ns	ns	< 0.001	< 0.001	< 0.001
Procedure Group	0.008	0.914	0.091	0.002	0.487	0.011
PTCA/Stent/Tear Same Day as CABG/Valve Surgery	0.011	0.579	0.043	not tested[1]	not tested[1]	not tested[1]

ns: not significant

[1] This variable was not tested because the preliminary analysis did not suggest that the variable would be predictive of the relevant outcome.

Measures of model adequacy. To evaluate the model performance for both the development and cross-validation samples, the estimated coefficients from the development model were applied to both samples. The coefficients from the final model were applied to the full data set. The resultant *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[2]. The *c* statistic ranges between 0.5 and 1.0, with higher values associated with better discrimination, and can be expressed as a percentage ranging from 50 to 100 percent. In some respects, the *c* statistic is similar to the R^2 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 models are listed in Table 4.

Table 4. c Statistics for Development, Cross-Validation, and Full Data Set Models

Measure	Development Model %	Cross-Validation Model %	Full Data Set Model %
In-Hospital Mortality	83.0	82.2	83.0
Operative Mortality	82.1	77.8	80.9
7-Day Readmissions	62.3	57.5	59.9
30-Day Readmissions	62.5	60.7	61.9

[2] 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

The coefficients and odds ratios for each risk factor included in the final models are listed in Tables 5a and 5b. The entire data set was used in creating the final coefficients (i.e., the development sample and the cross-validation sample were "recombined", and the coefficients were re-estimated). 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, the odds ratio for ASA Class 5 is 4.943 for the in-hospital mortality model, meaning that a patient with an anesthesia class of five was almost 5 times as likely to die during the hospital admission as patients not assigned to this classification. Odds ratios are not applicable for continuous variables such as age in years and percent of left main stenosis.

Table 5a. Coefficients and Odds Ratios of Final Mortality Models

Predictor Variables	In-hospital Mortality		Operative Mortality	
	Coefficient	Odds Ratio	Coefficient	Odds Ratio
Constant	-6.4502		-6.0240	
Demographic Variables				
Age in Years	0.0123	NA	0.0124	NA
Age # Years > 65	0.0454	NA	0.0470	NA
Female	0.4906	1.633	0.4183	1.519
Laboratory Variables				
Albumin < 3.1	0.1892	1.208	0.0369	1.038
BUN > 40	0.2618	1.299	0.2994	1.349
Creatinine > 1.4	0.3722	1.451	0.2888	1.335
Glucose > 165	0.0609	1.063	not tested[1]	not tested[1]
Clinical Variables Other Than Laboratory Variables				
AMI Other Inferior Wall Initial Episode	0.7111	2.036	0.4818	1.619
AMI Except Other Anterior or Other Inferior Wall	0.3404	1.405	ns	ns
ASA Class 5	1.5980	4.943	1.5404	4.666
ASA Emergency Flag	0.5782	1.783	0.5871	1.799
Cachexia	1.3338	3.796	1.2851	3.615
CAD > 70, 5-7 Vessels Grp	0.0122	1.012	0.1390	1.149
Cancer	not tested[1]	not tested[1]	0.3627	1.437
Cardiogenic Shock, Preoperative	1.0169	2.765	0.8835	2.419
Coagulopathy	1.3296	3.780	ns	ns
Current Med Immunosuppressants	0.3362	1.400	0.3795	1.462
Current Med Insulin	0.3357	1.399	0.3017	1.352
Ejection Fraction				
<25%	0.2564	1.292	0.2608	1.298
25-45%	0.1936	1.214	0.1292	1.138
>45%	*	*	*	*
Heart Failure	0.6913	1.996	0.6141	1.848
History of CABG or Valve Surgery	0.6932	2.000	0.5449	1.724
History of Peripheral Vascular Disease	0.2731	1.314	0.2516	1.286
Hypertension with Complications	0.6096	1.840	0.6199	1.859
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery	ns	ns	0.4316	1.540
Liver Disease	1.1361	3.115	not tested[1]	not tested[1]
MI/AMI Other Anterior Wall	0.4314	1.539	0.2351	1.265
Mild Moderate or Severe AMS	0.2313	1.260	0.3866	1.472
Multiple Valve Procedures	ns	ns	0.4506	1.569
Other CV Procedure Group	0.4133	1.512	0.3291	1.390
Percent of Left Main Stenosis	0.000705	NA	not tested[1]	not tested[1]
Procedure Group				
CABG without Valve	*	*	*	*
Valve without CABG	0.2011	1.223	0.0566	1.058
Valve with CABG	0.9144	2.495	0.7931	2.210
PTCA/Stent/Tear Same Day as CABG/Valve Surgery	0.7988	2.223	0.5054	1.658
Septal Other Anomalous Repair Heart	0.4216	1.524	0.3298	1.391
SIRS Group	0.1818	1.199	0.2920	1.339

[1] This variable was not tested because the preliminary analysis did not suggest that the variable would be predictive of the relevant outcome.

* This is the reference level for the variable.

NA: Not applicable. This factor was tested as a continuous variable.

ns: Not significant in development model.

Table 5b. Coefficients and Odds Ratios of Final Readmissions Models

Predictor Variables	7-day Readmissions		30-day Readmissions	
	Coefficient	Odds Ratio	Coefficient	Odds Ratio
Constant	-3.1575		-2.7260	
Demographic Variables				
Age # Years > 65	0.0191	NA	0.0119	NA
Female	ns	ns	0.1824	1.200
Clinical Variables Other Than Laboratory Variables				
Chronic Lung Disease	0.3512	1.421	0.2133	1.238
Diabetes				
No Diabetes	not tested[1]	not tested[1]	*	*
Diabetes without Complication	not tested[1]	not tested[1]	0.2015	1.223
Diabetes with Complication	not tested[1]	not tested[1]	0.3900	1.477
Diabetes with Long Term/Unspecified Complications	0.3496	1.418	not tested[1]	not tested[1]
Heart Failure	0.3485	1.417	0.0906	1.095
History of Peripheral Vascular Disease	not tested[1]	not tested[1]	0.2175	1.243
MediQual Predicted Length of Stay	ns	ns	0.0564	NA
Procedure Group				
CABG without Valve	*	*	*	*
Valve without CABG	0.1159	1.123	0.1893	1.208
Valve with CABG	0.1995	1.221	0.1130	1.120
PTCA/Stent/Tear Same Day as CABG/Valve Surgery	0.5823	1.790	not tested[1]	not tested[1]

[1] This variable was not tested because the preliminary analysis did not suggest that the variable would be predictive of the relevant outcome.
* This is the reference level for the variable.
NA: Not applicable. This factor was tested as a continuous variable.
ns: Not significant in development model.

Calculation of Statistical Ratings

Once the risk-adjustment models were built for each outcome measure (in-hospital mortality, operative mortality, 7-day readmissions, and 30-day readmissions), the statistical ratings were calculated. In doing so, actual rates were compared to expected rates to determine whether the difference was statistically significant.

Determining Actual (Observed) Rates

In-hospital mortality rates were determined by dividing the total number of deaths that occurred during the hospital stay by the total number of cases included in the analysis.

Operative mortality rates were determined by dividing the total number of deaths that occurred during the hospital stay *and* within 30 days of the CABG/valve surgery date by the total number of cases included in the analysis.

Seven-day and 30-day readmissions were determined by dividing the total number of cases readmitted to a general acute care hospital (for particular principal diagnoses) within 7 or 30 days of discharge from the original hospital by the total number of cases included in the analysis.

Determining Expected Rates

The first step in calculating the expected rates was to estimate the probability of each of the relevant events occurring for each patient, that is: 1) the probability of in-hospital death, 2) the probability of death in the hospital or within 30 days, 3) the probability of being readmitted within 7 days, and 4) the probability of being readmitted within 30 days. The probability of each of these events occurring was estimated by using the statistical technique of logistic regression. In logistic regression each category for each clinical or demographic risk factor was assigned a coefficient or "weight." A factor category's weight was higher (or lower) if patients with that factor category tended to have a higher (or lower) chance of the event occurring. These weights, determined using the statewide CABG and valve data set, were used to estimate each individual patient's probability of in-hospital death, operative death (in-hospital or within 30 days), or 7-day or 30-day readmissions given the risk factors of the patient. (Note that coefficients are displayed in Tables 5a and 5b in the "Coefficients and Odds Ratios" section.)

The results for all patients were then summed to determine the expected number of in-hospital deaths, deaths in the hospital or within 30 days, and readmissions within 7 days or 30 days for a given hospital/surgeon. The expected rate was calculated by dividing the total number of expected events by the total number of cases in the analysis.

The following example of the in-hospital mortality analysis illustrates the calculations used in determining the statistical ratings. Similar calculations apply to operative mortality and 7-day and 30-day readmissions.

Example 1: Calculations of Statistical Ratings for In-Hospital Mortality Analysis

Total Cases: Number of hospitalizations after exclusions.

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

Percentage: Total number of deaths / Total Cases

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

Percentage: Total number of expected deaths / Total Cases

To calculate a patient's probability of death:

Step 1: Calculate βX:

βX = -6.4502*(constant)* + 0.0123(Age in Years) + 0.0454(Age # Years > 65) + 0.4906(Female) + 0.1892(Albumin < 3.1) + 0.2618(BUN > 40) + 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: (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

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

POST-SURGICAL LENGTH OF STAY ANALYSIS

Risk-Adjustment Methodology

Data Preparation

After cases to be excluded from the post-surgical length of stay analysis were removed, the remaining cases were split into two equal-size samples by procedure group (CABG without valve, valve without CABG, and valve with CABG)—a development sample and a cross-validation sample. The relevant number of cases for each sample is shown in Table 6.

Table 6. ***Case Counts and Average Length of Stay in Days***

	Development Sample	Cross-Validation Sample	Full Data Set
Number of cases	8,321	8,318	16,639
Average length of stay *(arithmetic)*	7.2	7.2	7.2
Average length of stay *(geometric)*	6.3	6.3	6.3

Building the Risk-Adjustment Model

While logistic regression was used to construct the models for in-hospital mortality, operative mortality, 7-day readmissions, and 30-day readmissions, a general linear modeling approach was used for post-surgical length of stay because it is a continuous variable. The model building steps were similar to those in the logistic regression models.

Model selection. The model was constructed using the development sample, after a natural log transformation was done to adjust for skewness in the distribution. All tests of significance ($p < 0.10$) were based on general linear model *F*-tests. The results for the development model are shown in Table 7.

Table 7. Development Model: Variables Tested as Potential Predictors of Post-Surgical Length of Stay

Candidate Variables	Results
Demographic Variables	
Age in Years	✓
Age # Years > 65	✓
Female	✓
Race	✓
Clinical Variables Other Than Laboratory Variables	
Acute Myocardial Infarction (AMI)	ns
Anemia	✓
Cachexia	✓
Cancer	ns
Cardiogenic Shock, Preoperative	✓
Chronic Lung Disease	✓
Chronic Pulmonary Hypertension	ns
Coagulopathy	✓
Diabetes with Long Term/Unspecified Complications	✓
Excision of Other Lesion/Heart Tissue, Open Approach – Same Date as Valve Surgery w/wo CABG	ns
Heart Failure	✓
History of CABG or Valve Surgery	ns
Hypertension with Complications	✓
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery	✓
Liver Disease	✓
MediQual Predicted Length of Stay	✓
Multiple Valve Procedures	✓
Other Open Heart Procedure	✓
Procedure Group	✓
PTCA/Stent Same Day as CABG/Valve Surgery	✓
Renal Failure/Dialysis (binary)	✓

✓ : significant predictor ($p < 0.10$)
ns: not significant

Cross-validation. After the development model was built for post-surgical length of stay, the model was cross-validated. In order to determine which factors remained significant when the development model was applied to the cross-validation sample, the model built in the model selection process was re-estimated using the cases in the cross-validation sample.

Table 8 presents the probability values (*p*-values) in the development and cross validation samples for each of the significant variables. All candidate variables that were significant in the development model did cross validate.

Table 8. Cross-Validation Results: p-values for Significant Candidate Variables in the Post-Operative Length of Stay Development Model

Significant Variables in Development Model	Development Model	Cross-Validation Model
Demographic Variables		
Age in Years	< 0.0001	< 0.0001
Age # Years > 65	0.0005	0.0494
Female	0.0006	0.0003
Race	< 0.0001	< 0.0001
Clinical Variables Other Than Laboratory Variables		
Anemia	0.0016	0.0150
Cachexia	< 0.0001	< 0.0001
Cardiogenic Shock, Preoperative	0.0006	0.0001
Chronic Lung Disease	< 0.0001	< 0.0001
Coagulopathy	0.0218	0.0966
Diabetes with Long Term/Unspecified Complications	0.0493	0.0810
Heart Failure	< 0.0001	< 0.0001
Hypertension with Complications	0.0114	< 0.0001
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery	< 0.0001	0.0003
Liver Disease	0.0028	0.0349
MediQual Predicted Length of Stay	< 0.0001	< 0.0001
Multiple Valve Procedures	< 0.0001	< 0.0001
Other Open Heart Procedure	0.0002	0.0074
Procedure Group	< 0.0001	< 0.0001
PTCA/Stent Same Day as CABG/Valve Surgery	0.0002	0.0090
Renal Failure/Dialysis (binary)	0.0020	< 0.0001

Measure of model adequacy. To evaluate the model performance for both the development and cross-validation samples, the estimated coefficients from the development model were applied to both samples. The coefficients from the final model were applied to the full data set. The Coefficient of Determination (R^2) was the measure considered in evaluating the models' performance. R^2 refers to the percentage of the total variability in post-surgical length of stay among the patients in the sample that can be explained by the estimated model involving the specified risk factors. R^2 values for each of the models are listed in Table 9.

Table 9. Post-Surgical Length of Stay Model: R-Squared Statistics for Development, Cross-Validation, and Full Data Set

Development Model %	Cross-Validation Model %	Full Data Set Model %
26.4	28.5	27.4

Coefficients

Each category for each statistically significant clinical or demographic factor was assigned a coefficient or weight. These coefficients were used to compute each individual patient's expected post-surgical length of stay given the risk factors of the patient. Table 10 displays the coefficients and associated *p*-values for the variables included in the final model.

Table 10. Coefficients of Predictors in the Final Post-Surgical Length of Stay Model

Predictor Variables	Coefficient	*p*-value
Constant	1.108624889	
Demographic Variables		
Age in Years	0.005026248	< 0.0001
Age # Years > 65	0.003972403	0.0001
Female	0.035667305	< 0.0001
Race		< 0.0001
White	*	
Black	0.155841396	
Other/Unknown	0.089618419	
Clinical Other Than Laboratory Variables		
Anemia	0.034843645	< 0.0001
Cachexia	0.437533476	< 0.0001
Cardiogenic Shock, Preoperative	0.256911721	< 0.0001
Chronic Lung Disease	0.085190606	< 0.0001
Coagulopathy	0.154126236	0.0040
Diabetes with Long Term/Unspecified Complications	0.035857522	0.0080
Heart Failure	0.177852863	< 0.0001
Hypertension with Complications	0.083094735	< 0.0001
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery	0.087367574	< 0.0001
Liver Disease	0.163314581	0.0002
MediQual Predicted Length of Stay	0.021189134	< 0.0001
Multiple Valve Procedures	0.152126156	< 0.0001
Other Open Heart Procedure	0.058931364	< 0.0001
Procedure Group		< 0.0001
CABG without Valve	*	
Valve without CABG	0.058686262	
Valve with CABG	0.160233381	
PTCA/Stent Same Day as CABG/Valve Surgery	0.166666666	< 0.0001
Renal Failure/Dialysis (binary)	0.104868605	< 0.0001

* This is the reference level for the variable.

Calculation of Risk-Adjusted Post-Surgical Length of Stay

Once the significant risk factors were determined, the actual post-surgical length of stay and the expected post-surgical length of stay were used to calculate the risk-adjusted post-surgical length of stay.

Actual Length of Stay

The actual post-surgical length of stay was derived by subtracting the CABG/valve procedure date from the discharge date. The average post-surgical length of stay is reported as a geometric mean[1], rather than an arithmetic mean.

Expected Length of Stay

Coefficients in the final model were summed to compute each individual patient's expected length of stay, given the risk factors of the patient. The coefficient for a category represented the estimated difference in mean (log) length of stay for the category compared to the base category of that factor. Thus, the coefficient for the base category of a factor was always 0. When dealing with categorical variables in the length of stay model there was no particular importance to the order of these categories. The constant term in the model represents the predicted value for all categorical factors at the base level. The coefficients for the other levels within a factor represent adjustments to that "baseline." No adjustment was required at the base level for any factor, because it was already accounted for in the constant. For example, a patient without heart failure had a "0" or "baseline" coefficient; while a patient with heart failure would be adjusted upward by 0.177852863 (see Table 10). The order was not important because each ordering scheme would result in different coefficients, but the estimated difference between any pairs of levels would be the same (i.e., the difference between heart failure and no heart failure would always be 0.177852863 independent of what the specific coefficients were for each). For quantitative factor age, there is always an adjustment because the "baseline" is 0.

Risk-Adjusted Post-Surgical Length of Stay

Post-surgical length of stay is reported in average days instead of a statistical rating. Unlike other measures (such as mortality where a lower number of deaths is obviously better than a higher number), it is not known whether shorter lengths of stay are "better" than longer lengths of stay or vice versa. Reporting the average length of stay in days, therefore, presents information that can be used to examine differences in lengths of stay without taking a position on what is "best."

The following example illustrates the complete calculation.

[1] Because a natural log transformation of each length of stay value was done to adjust for skewness in the distribution, it was necessary to convert the logarithm values back to days when reporting or displaying post-surgical length of stay. This process results in geometric means, rather than arithmetic means. Unlike an arithmetic mean that is derived by summing individual values and dividing by the number of observations, a geometric mean is calculated by multiplying the individual values and taking the n^{th} root of the product. Geometric means are averages and are the natural result when using the log transformation.

Example 2: Calculations Used for Post-Surgical Length of Stay Analysis

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

Actual Mean LOS: Geometric mean of the length of stay across Total Cases

Calculate geometric mean length of stay (GMLOS):

Step 1: Calculate the natural log (**ln**) of GMLOS:

$$\mathbf{ln}(\text{GMLOS}) = (1/n)(\mathbf{ln}\text{LOS}_{\text{case 1}} + \mathbf{ln}\text{LOS}_{\text{case 2}} + \ldots + \mathbf{ln}\text{LOS}_{\text{case n}})$$

Step 2: Convert **ln**(GMLOS) to GMLOS (i.e., convert to days):

$$\text{GMLOS} = e^{\mathbf{ln}(\text{GMLOS})} \quad \text{where } e \approx 2.7182818285$$

Expected Mean LOS: Geometric mean of the *expected* length of stay for Total Cases

Calculate geometric mean of the *expected* length of stay (GM*E*LOS):

Step 1: Calculate each patient's *E***ln**LOS:

$$E\mathbf{ln}\text{LOS} = (\text{constant}) + (\text{risk factor category coefficients relevant to each patient})$$

Step 2: Calculate the **ln**GM*E*LOS:

$$\mathbf{ln}(\text{GM}E\text{LOS}) = (1/n)(E\mathbf{ln}\text{LOS}_{\text{case 1}} + E\mathbf{ln}\text{LOS}_{\text{case 2}} + \ldots + \mathbf{ln}\text{LOS}_{\text{case n}})$$

Step 3: Convert the **ln**(GM*E*LOS) to GM*E*LOS (i.e., convert to days):

$$\text{GM}E\text{LOS} = e^{\mathbf{ln}(\text{GM}E\text{LOS})} \quad \text{where } e \approx 2.7182818285$$

Calculate a patient's *expected* length of stay (*E*LOS):

Convert the *E***ln**LOS to *E*LOS (i.e., convert to days):

$$E\text{LOS} = e^{(E\mathbf{ln}\text{LOS})} \quad \text{where } e \approx 2.7182818285$$

Risk-Adjusted Length of Stay: Average length of stay / expected average length of stay x state average post-surgical length of stay for a given reporting group.

ln = natural logarithm (base e)

AVERAGE HOSPITAL CHARGE ANALYSIS

Average charges were trimmed for outliers and case-mix adjusted separately for the three procedure groups: CABG without valve, valve without CABG, and valve with CABG. Average charge is reported for hospitals only.

Construction of Reference Database

After standard, invalid charges, and low volume exclusions were applied, the charge data for each procedure group were analyzed by region and by groups based on DRG assignment. Patients who underwent CABG without valve procedures were comprised of the following DRG (Diagnostic Related Group) groups:

DRG Group 1	DRG 106	Coronary Bypass with PTCA
DRG Group 2	DRG 107[1]	Coronary Bypass with Cardiac Catheterization
	DRG 547[2]	Coronary Bypass with Cardiac Catheterization with Major Cardiovascular Diagnosis
	DRG 548[2]	Coronary Bypass with Cardiac Catheterization without Major Cardiovascular Diagnosis
DRG Group 3	DRG 108	Other Cardiothoracic Procedures
DRG Group 4	DRG 109[1]	Coronary Bypass without Cardiac Catheterization
	DRG 549[2]	Coronary Bypass without Cardiac Catheterization with Major Cardiovascular Diagnosis
	DRG 550[2]	Coronary Bypass without Cardiac Catheterization without Major Cardiovascular Diagnosis

[1] DRG 107 and 109 were invalid beginning October 1, 2005
[2] DRG 547, 548, 549, and 550 were effective October 1, 2005

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

DRG Group 5	DRG 104	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization
DRG Group 6	DRG 105	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization

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 mean.

For each of the procedure groups, trim points were calculated for each DRG group within each region. Cases with a charge that was 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.

Since charges varied dramatically among regions, upper and lower trim points were calculated at the regional level for each DRG group within each procedure group.

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)

See Tables 11a through 11c for upper trim points, percent of outliers, and average charge after trimming for each DRG group within each region for each of the procedure groups.

Table 11a. CABG without Valve: Trim Points for Average Charge

DRG Group	Upper Trim Point*	Outlier %	Average Charge After Trimming
Group 1 (DRG 106)			
Region 1	$514,164	1.0	$134,452
Region 2	$460,003	0.0	$161,463
Region 3	**	**	**
Region 4	$288,637	7.7	$122,030
Region 5	$234,503	6.3	$91,068
Region 6	$230,857	3.8	$87,315
Region 7	$293,723	0.0	$123,375
Region 8	$686,110	1.8	$205,550
Region 9	$934,467	0.0	$287,957
Group 2 (DRG 107, 547, 548)			
Region 1	$317,711	1.2	$86,930
Region 2	$284,794	2.0	$113,957
Region 3	$129,349	2.4	$66,111
Region 4	$207,730	0.9	$77,294
Region 5	$177,625	1.7	$72,596
Region 6	$163,778	0.7	$67,838
Region 7	$238,417	3.7	$92,297
Region 8	$547,634	1.2	$152,699
Region 9	$668,819	1.8	$205,447
Group 3 (DRG 108)			
Region 1	$372,017	1.7	$134,704
Region 2	$235,309	0.0	$110,554
Region 3	$188,483	3.8	$76,024
Region 4	**	**	**
Region 5	$375,028	0.0	$92,815
Region 6	$173,116	3.2	$79,725
Region 7	$213,911	2.1	$84,490
Region 8	$400,727	5.3	$128,140
Region 9	**	**	**

Table 11a. continued

DRG Group	Upper Trim Point*	Outlier %	Average Charge After Trimming
Group 4 (DRG 109, 549, 550)			
Region 1	$351,993	0.8	$84,912
Region 2	$171,866	3.3	$79,561
Region 3	$85,710	1.5	$49,117
Region 4	$144,733	3.2	$60,635
Region 5	$130,571	2.9	$53,890
Region 6	$109,859	1.7	$45,808
Region 7	$165,279	7.9	$64,609
Region 8	$357,544	0.5	$109,321
Region 9	$622,695	0.9	$173,226

* Charges of less than $10,000 were considered invalid. Therefore, with the exception of Group 4 in Region 3, there were no lower trim points. The lower trim point for Group 4 in Region 3 was $11,204.

** These regions under the DRG group were excluded from analysis due to low volume.

Table 11b. Valve without CABG: Trim Points for Average Charge

DRG Group	Upper Trim Point*	Outlier %	Average Charge After Trimming
Group 5 (DRG 104)			
Region 1	$520,142	1.3	$149,014
Region 2	$444,688	2.8	$163,666
Region 3	$227,337	2.5	$92,233
Region 4	$387,862	0.0	$127,811
Region 5	$245,921	3.4	$96,121
Region 6	$229,462	2.4	$95,536
Region 7	$371,970	1.1	$125,590
Region 8	$667,513	1.1	$217,027
Region 9	$859,504	0.0	$266,726
Group 6 (DRG 105)			
Region 1	$413,432	0.5	$111,255
Region 2	$246,473	5.8	$100,838
Region 3	$170,114	3.2	$72,736
Region 4	$334,194	1.1	$113,065
Region 5	$148,180	3.6	$66,438
Region 6	$173,366	0.9	$71,698
Region 7	$241,280	3.3	$90,595
Region 8	$466,089	1.4	$155,036
Region 9	$581,332	1.9	$183,671

*Charges of less than $10,000 were considered invalid; therefore, there were no lower trim points.

Table 11c. Valve with CABG: Trim Points for Average Charge

	Upper Trim Point*	Outlier %	Average Charge After Trimming
Group 5 (DRG 104)			
Region 1	$614,589	0.7	$167,257
Region 2	$415,786	0.0	$174,479
Region 3	$193,951	3.6	$103,572
Region 4	$409,935	2.7	$145,684
Region 5	$323,966	0.0	$118,208
Region 6	$286,539	1.9	$119,407
Region 7	$506,466	0.6	$156,178
Region 8	$773,188	1.0	$218,425
Region 9	$1,054,601	0.0	$324,165
Group 6 (DRG 105)			
Region 1	$524,766	1.5	$136,022
Region 2	$313,659	1.0	$129,502
Region 3	$201,594	2.4	$90,290
Region 4	$386,353	6.1	$114,249
Region 5	$197,783	3.0	$79,890
Region 6	$184,722	6.3	$79,657
Region 7	$363,162	2.4	$107,683
Region 8	$595,191	2.9	$168,638
Region 9	$780,464	2.7	$241,443

* Charges of less than $10,000 were considered invalid. Therefore, with the exception of Group 5 in Region 3, there were no lower trim points. The lower trim point for Group 5 in Region 3 was $10,668.

Case-Mix Adjustment of Average Hospital Charge

Case-mix adjustment was used to adjust the average charge reported for hospitals after all exclusions were satisfied and outlier trimming was performed. A case-mix adjusted charge is reported separately for each reporting group for which the hospital had at least 5 cases. Charges were adjusted to account for differences in regional charges and the number of patients that a hospital had for each DRG group of patients within each procedure group.

To determine the case-mix adjusted charges at a particular hospital, first the actual charges were calculated for each reporting group. Next, expected charges were calculated for each reporting group. Expected charges were based on the average charges for each DRG group and region within each procedure group. The case-mix adjusted charge was calculated by dividing the mean actual charges by the mean expected charge for the hospital, and then multiplying this quantity by the average charge for the hospital's region for the relevant reporting group. The following example illustrates how the case-mix adjusted charge was computed for a hospital in Region 1 for the valve without CABG report group:

Example 3: Calculations Used in Determining Case-Mixed Average Charge for a Hospital

Region 1: Southwestern PA
Report Group*:* Valve without CABG

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

Actual Charge: Mean of the charges for each hospitalization.

Expected Charge: Mean of the predicted charges for each hospitalization.

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

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

Region 1 - Southwestern PA, valve without CABG, DRG104: $149,014
or
Region 1 - Southwestern PA, valve without CABG, DRG105: $111,255

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

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

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

AVERAGE PAYMENT ANALYSIS

Average commercial and/or Medicare payment is reported for hospitals only. Commercial payment data were received by PHC4 from commercial payors and Medicare payment data were provided by the Centers for Medicare and Medicaid Services (CMS).

After cases meeting standard exclusion criteria were removed, analysis of commercial and/or Medicare payment was performed for cases that could be linked to valid payment data. Payments of less than $5,000 were considered invalid and were not included in the linking process. Data elements in the discharge record such as social security number, gender, date of birth, admission date, and discharge date were used to match cases to payment information. Table 12 displays the number of cases statewide for which commercial and Medicare payment data could be linked.

Table 12. Number of Cases for Which Payment Data Could be Linked

Payor Type	# of Cases	Average Payment
Commercial Insurance	2,993	$33,355
Medicare	7,109	$34,257

Note that payment data was not trimmed for outliers or case-mix adjusted.

Average Commercial Payment

The average commercial payment reported for hospitals is *the actual mean payment for all the cases that were successfully linked to commercial payment data.* That is, the average commercial payment for each procedure group is the sum of all payments at the hospital for cases within that procedure group with commercial payment data divided by the total number of cases with commercial payment data for the hospital. The average commercial payment is only reported for procedure groups with at least 5 cases in the commercial payment analysis.

Average Medicare Payment

The average Medicare payment reported for hospitals is *the actual mean payment for cases that were successfully linked to Medicare payment data.* That is, the average Medicare payment for each procedure group is the sum of all payments at the hospital for cases within that procedure group with Medicare payment data divided by the total number of cases with Medicare payment data for the hospital. Currently, the average Medicare payment is only reported for procedure groups with at least 13 cases in the Medicare payment analysis.

APPENDICES

APPENDIX A: EXCLUSION DEFINTIONS

Table A. Major Organ Transplants

ICD-9-CM Code	Description
Procedure code in any position:	
37.51, 37.52, 37.53	Heart transplant
33.50. 33.51, 33.52	Lung transplant
33.6	Combined heart and lung transplant
55.61, 55.69	Kidney transplant
50.51, 50.59	Liver transplant

Table B. Study DRGs (Diagnostic Related Groups): Cases not in the following DRGs were excluded from the study

CABG without Valve	
DRG 103	Heart Transplant or Implant of Heart Assist System
DRG 106	Coronary Bypass with PTCA
DRG 107[1]	Coronary Bypass with Cardiac Catheterization
DRG 108	Other Cardiothoracic Procedures
DRG 109[1]	Coronary Bypass without Cardiac Catheterization
DRG 515	Cardiac Defibrillator Implant without Cardiac Catheterization
DRG 525	Other Heart Assist System Implant
DRG 535	Cardiac Defibrillator Implant with Cardiac Catheterization with Acute Myocardial Infarction, Heart Failure, or Shock
DRG 536	Cardiac Defibrillator Implant with Cardiac Catheterization without Acute Myocardial Infarction, Heart Failure, or Shock
DRG 541[2] and MDC 5	Tracheostomy with Mechanical Ventilation 96+ Hours or Principal Diagnosis Except Face, Mouth, Neck with Major O.R. Procedures
DRG 547[3]	Coronary Bypass with Cardiac Catheterization with Major Cardiovascular Diagnosis
DRG 548[3]	Coronary Bypass with Cardiac Catheterization without Major Cardiovascular Diagnosis
DRG 549[3]	Coronary Bypass without Cardiac Catheterization with Major Cardiovascular Diagnosis
DRG 550[3]	Coronary Bypass without Cardiac Catheterization without Major Cardiovascular Diagnosis
Valve with CABG, Valve without CABG	
DRG 103	Heart Transplant or Implant of Heart Assist System
DRG 104	Cardiac Valve and Other Major Cardiothoracic Procedures with Cardiac Catheterization
DRG 105	Cardiac Valve and Other Major Cardiothoracic Procedures without Cardiac Catheterization
DRG 108	Other Cardiothoracic Procedures
DRG 515	Cardiac Defibrillator Implant without Cardiac Catheterization
DRG 525	Other Heart Assist System Implant
DRG 535	Cardiac Defibrillator Implant with Cardiac Catheterization with Acute Myocardial Infarction, Heart Failure, or Shock
DRG 536	Cardiac Defibrillator Implant with Cardiac Catheterization without Acute Myocardial Infarction, Heart Failure, or Shock
DRG 541[2] and MDC 5	Tracheostomy with Mechanical Ventilation 96+ Hours or Principal Diagnosis Except Face, Mouth, Neck with Major O.R. Procedures

[1] DRG 107 are 109 were invalid beginning October 1, 2005

[2] DRG 541 has an updated description and an additional procedure, Extracorporeal membrane oxygenation (code 39.65), effective October 1, 2005

[3] DRG 547, 548, 549, and 550 were effective October 1, 2005

APPENDIX A: EXCLUSION DEFINTIONS *continued*

Table C. *Clinical Complexity ICD-9-CM Codes*

ICD-9-CM Code	Description
Clinical Complexity Exclusions Applicable to All Procedure Groups	
Diagnosis or procedure code in any position:	
32.22	Lung volume reduction surgery performed at the same time as Open Heart Procedure
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
35.54	Repair of endocrinal 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	Repair of other and unspecified repair of unspecified septal defect of heart
35.72	Repair of other and unspecified of ventricular septal defect
35.73	Repair of other and unspecified of endocardial cushion defect
35.81	Total repair of tetralogy of Fallot
35.82	Total repair of Anomalous pulmonary venous connection
35.83	Total repair of truncus arteriosus
35.84	Total correction of transposition of great vessels, NEC
35.91	Intratrial transposition of venous return
35.92	Creation of conduit right ventricle and pulmonary artery
35.93	Creation of conduit 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
38.12	Carotid endarterectomy
38.34	Resection of aorta with anastomosis
38.35	Resection of thoracic vessel with anastomosis
38.36	Resection of abdominal arteries with anastomosis
38.44	Resection of aorta with replacement
38.45	Resection of thoracic vessel with replacement
38.46	Resection of abdominal arteries with replacement
39.51	Clipping of aneurysm
39.52	Other aneurysm repair
39.71	Endovascular implantation of graft in abdominal aorta
39.73	Endovascular implantation of graft in thoracic aorta
423.2, 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
V42.0	Kidney replaced by transplant
V42.1	Heart replaced by transplant
V42.6	Lung replaced by transplant
V42.7	Liver replaced by transplant

APPENDIX A: EXCLUSION DEFINTIONS *continued*

Table C. ***Clinical Complexity ICD-9-CM Codes*** **continued**

ICD-9-CM Code	Description
Clinical Complexity Exclusions Applicable to CABG without Valve Procedure Group	
Procedure code 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
Clinical Complexity Exclusions Applicable to Valve without CABG Procedure Group	
Principal diagnosis position only:	
038.x, 38.xx	Septicemia
421.0	Acute and subacute bacterial endocarditis
421.1	Acute and subacute infective endocarditis, 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
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 code in any position:	
277.3, 425.7	Amyloidosis plus nutritional & metabolic cardiomyopathy (both codes must be present)
414.10	Aneurysm of heart (wall)
414.19	Aneurysm of heart
Clinical Complexity Exclusions Applicable to Valve with CABG Procedure Group	
Principal diagnosis position only:	
038.x, 38.xx	Septicemia
421.0	Acute and subacute bacterial endocarditis
421.1	Acute and subacute infective endocarditis, 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
996.02	Mechanical complication of cardiac device, implant, and graft due to heart valve prosthesis
996.61	Infection and inflammatory reaction due to cardiac device/implant/graft
996.71	Other complication of internal prosthetic device due to heart valve prosthesis
Diagnosis code in any position:	
277.3, 425.7	Amyloidosis plus nutritional & metabolic cardiomyopathy (both codes must be present)
414.10	Aneurysm of heart (wall)
414.19	Other aneurysm of heart
Procedure code 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 B: EXCLUSION DATA

Specific cases were excluded from the analysis. Exclusion criteria that were relevant to all outcome measures (i.e., standard exclusions) were first applied to the in-hospital mortality analysis (see Table A below). For the other outcome measures in the report, additional exclusion criteria were applied as appropriate.

Table A. Exclusions for In-Hospital Mortality Analysis

	Cases		In-Hospital Mortality	
	#	%	#	%
Total cases prior to in-hospital mortality exclusions	*19,271*	*100.0*	*682*	*3.5*
Exclusions:				
• Patients < 30 years of age	127	0.7	7	5.5
• Patients who left against medical advice	18	0.1	0	0.0
• Clinically complex cases[1]	1,795	9.3	168	9.4
Total exclusions	*1,940*	*10.1*	*175*	*9.0*
Total cases remaining in analysis	***17,331***	***89.9***	***507***	***2.9***

[1] Clinically complex cases included major organ transplant cases (see Appendix A, Table A), cases *not* in the study DRGs (See Appendix A, Table B for DRGs in the study), and clinically complex cases based on ICD-9-CM codes (see Appendix A, Table C), and cases granted special request for exclusion.

Table B. Additional Exclusions for Operative Mortality Analysis

	Cases		Operative Mortality	
	#	%	#	%
Total cases after in-hospital mortality exclusions	*17,331*	*100.0*	—	—
Additional Exclusions:				
• Cases with invalid/inconsistent data[1]	91	0.5	—	—
• Out-of state residents[2]	1,496	8.6	—	—
Total exclusions	*1,587*	*9.2*	—	—
Total cases remaining in analysis	***15,744***	***90.8***	***546***	***3.5***

[1] Cases with invalid/inconsistent data (i.e., social security number, date of birth, or sex) could not be linked to death certificate information.

[2] Out-of-state residents were excluded because death certificate data was not available for these patients.

Table C. Additional Exclusions for 7-day and 30-day Readmissions Analyses

	Cases		Readmissions	
	#	%	7-day %	30-day %
Total cases after in-hospital mortality exclusions	*17,331*	*100.0*	—	—
Additional exclusions:				
• Patients who died during hospitalization in which surgery was performed	507	2.9	—	—
• Cases with invalid/inconsistent data[1]	84	0.5	—	—
• Out-of state residents[2]	1,443	8.3	—	—
Total exclusions	*2,034*	*11.7*	—	—
Total cases remaining in analysis	***15,297***	***88.3***	***6.0***	***15.0***

[1] Cases with invalid/inconsistent 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 home, and be readmitted there. Therefore, readmission data would not be available for these patients.

APPENDIX B: EXCLUSION DATA *continued*

Table D. *Additional Exclusions for Post-Surgical Length of Stay (LOS) Analysis*

	Cases		Average Post-Surgical LOS in Days
	#	%	
Total cases after in-hospital mortality exclusions	*17,331*	*100.0*	—
Additional exclusions:			
• Patients who died during hospitalization in which surgery was performed	507	2.9	—
• Cases that were length of stay outliers	185	1.1	—
Total exclusions	*692*	*4.0*	—
Total cases remaining in analysis	***16,639***	***96.0***	***7.2***

Table E. *Additional Exclusions for Average Hospital Charge Analysis*

	Cases		Average Charge
	#	%	
Total cases after in-hospital mortality exclusions	*17,331*	*100.0*	--
Additional exclusions:			
• Patients with invalid or missing charges[1]	3	< 0.1	--
• Cases that were charge outliers[2]	300	1.7	--
• Cases in low volume DRGs	538	3.1	
Total exclusions	*841*	*4.9*	--
Total cases remaining in analysis	***16,490***	***95.1***	***$115,097***

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

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

APPENDIX C: READMISSIONS DATA

A readmission was counted only if the patient was readmitted with a principal diagnosis that indicated a heart-related condition, an infection, and/or a complication related to the CABG and/or valve surgery. The following table includes only those diagnosis categories with at least one readmission. Data for readmissions were organized into the following categories: cardiac diagnoses, neurologic diagnoses, respiratory diagnoses, and other diagnoses including infections and complications of surgery. Note that some ICD-9-CM codes may not be listed in a category because there were no cases with the particular code.

		7-Day		***30-Day***	
		N = 918 (6.0 %)		*N = 2,299 (15.0 %)*	
Diagnosis	***ICD-9-CM Code***	#	%	#	%
CARDIAC DIAGNOSES					
Cardiac Dysrhythmias		**97**	**10.6**	**247**	**10.7**
Conduction disorders (i.e., av block)	426.x, 426.xx	4	0.4	10	0.4
Paroxysmal tachycardias	427.0, 427.1	2	0.2	6	0.3
Atrial fibrillation/flutter	427.31, 427.32	77	8.4	188	8.2
Ventricular fibrillation	427.41	0	0.0	2	0.1
Premature beats	427.61, 427.69	1	0.1	3	0.1
Other rhythm disorders (i.e., ectopic, nodal)	427.81, 427.89	13	1.4	38	1.7
Heart Failure/Hypertensive Heart Disease		**195**	**21.2**	**461**	**20.1**
Rheumatic heart failure	398.91	1	0.1	7	0.3
Unspecified hypertensive heart disease without/with heart failure	402.90, 402.91	0	0.0	6	0.3
Unspecified hypertensive renal disease with renal failure	403.91	1	0.1	3	0.1
Benign hypertensive renal disease with renal failure	403.11	0	0.0	1	<0.1
Unspecified hypertensive heart and renal disease with heart failure and renal failure	404.93	1	0.1	3	0.1
Congestive heart failure	428.x, 428.xx	160	17.4	369	16.1
Functional disturbances following cardiac surgery (i.e., post cardiotomy syndrome)	429.4	32	3.5	72	3.1
Coronary Atherosclerosis/Myocardial Ischemia/Infarction		**36**	**3.9**	**108**	**4.7**
Acute myocardial infarction (AMI)	410.x1	16	1.7	45	2.0
Postmyocardial infarction syndrome	411.0	6	0.7	14	0.6
Intermediate coronary syndrome	411.1	1	0.1	1	<0.1
Angina pectoris	413.x	0	0.0	1	<0.1
Coronary atherosclerosis	414.0x	11	1.2	43	1.9
Other forms of chronic ischemic heart disease	414.8	1	0.1	2	0.1
Chordae tendineae rupture	429.5	0	0.0	1	<0.1
Papillary muscle rupture	429.6	1	0.1	1	<0.1
Hypertension/Hypotension/Syncope/Dizziness	401.x, 458.x, 458.xx, 780.2, 780.4	**32**	**3.5**	**70**	**3.0**
Artery and Vein Disease/Embolism/Thrombosis		**19**	**2.1**	**61**	**2.7**
Vascular myelopathies	336.1	0	0.0	1	<0.1
Atherosclerosis of artery and vein graft	440.x, 440.xx	1	0.1	9	0.4
Abdominal and thoracic aortic aneurysm or dissection	441.x, 441.xx	2	0.2	14	0.6
Arterial embolism and thrombosis	444.xx	0	0.0	3	0.1
Atheroembolism of lower extremity	445.02	0	0.0	1	<0.1
Superficial phlebitis arm	451.82	1	0.1	1	<0.1
Venous embolism and thrombosis of deep vessels of lower extremity	453.40, 453.41, 453.42	4	0.4	16	0.7

APPENDIX C: READMISSIONS DATA *continued*

Diagnosis	ICD-9-CM Code	7-Day N = 918 (6.0 %) #	7-Day %	30-Day N = 2,299 (15.0 %) #	30-Day %
Artery and Vein Disease/Embolism/Thrombosis *continued*					
Venous embolism and thrombosis of other specified vein	453.8	2	0.2	3	0.1
Peripheral vascular complications	997.2	8	0.9	12	0.5
Vascular complications-vessel, not elsewhere classified	997.79	1	0.1	1	0.1
Other Forms of Heart Disease		**16**	**1.7**	**37**	**1.6**
Acute pericarditis	420.xx	1	0.1	6	0.3
Acute and subacute bacterial endocarditis	421.0	0	0.0	1	<0.1
Other diseases of pericardium (hemopericardium, restrictive)	423.x	13	1.4	28	1.2
Valve disorder: mitral, aortic	424.0, 424.1	2	0.2	2	0.1
NEUROLOGIC DIAGNOSES					
Encephalapathy	348.30, 348.31	**0**	**0.0**	**1**	**<0.1**
Retinal Vascular Occlusion, Unspecified	362.30	**2**	**0.2**	**5**	**0.2**
Stroke/Transient Cerebral Ischemia/Occlusion		**33**	**3.6**	**60**	**2.6**
Intracerebral hemorrhage	431	1	0.1	3	0.1
Occlusion and stenosis of precerebral arteries with and without infarction	433.xx	1	0.1	9	0.4
Occlusion of cerebral arteries with and without infarction	434.xx	25	2.7	39	1.7
Transient cerebral ischemia	435.x	5	0.5	8	0.3
Iatrogenic cerebrovascular infarction or hemorrhage	997.02	1	0.1	1	<0.1
RESPIRATORY DIAGNOSES					
Pulmonary Embolism/Infarction	415.xx	**27**	**2.9**	**75**	**3.3**
Aspiration Pneumonia	507.0	**32**	**3.5**	**68**	**3.0**
Pleurisy		**43**	**4.7**	**106**	**4.6**
Pleural effusion/atelectasis/pleurisy	511.x	41	4.5	102	4.4
Pneumothorax	512.x	2	0.2	4	0.2
Pulmonary Edema/Insufficiency		**27**	**2.9**	**42**	**1.8**
Interstitial emphysema	518.1	1	0.1	1	<0.1
Acute edema of lung, unspecified	518.4	2	0.2	2	0.1
Pulmonary insufficiency post trauma or surgery	518.5	0	0.0	1	<0.1
Acute respiratory failure	518.81	22	2.4	32	1.4
Acute and chronic respiratory failure	518.84	2	0.2	6	0.3
Respiratory and Other Chest Symptoms		**40**	**4.4**	**99**	**4.3**
Pulmonary congestion	514	1	0.1	1	<0.1
Trachea/bronchitis disease not elsewhere classified	519.1	0	0.0	2	0.1
Mediastinitis	519.2	0	0.0	1	<0.1
Tietze's disease (i.e. costochondritis)	733.6	0	0.0	2	0.1
Respiratory and other chest symptoms (e.g., shortness of breath, chest pain)	786.x, 786.xx	39	4.2	93	4.0

APPENDIX C: READMISSIONS DATA *continued*

Diagnosis	ICD-9-CM Code	7-Day N = 918 (6.0 %) #	7-Day %	30-Day N = 2,299 (15.0 %) #	30-Day %
OTHER DIAGNOSES					
Infections		**155**	**16.9**	**483**	**21.0**
Intestinal infection due to Clostridium difficile	008.45	8	0.9	25	1.1
Septicemia	038.xx	15	1.6	42	1.8
Pneumonia	481, 482.x, 482.xx, 485, 486	28	3.1	72	3.1
Empyema	510.9	0	0.0	2	0.1
Urinary tract infection	599.0	3	0.3	21	0.9
Cellulitis	682.x	6	0.7	12	0.5
Fever	780.6	9	1.0	14	0.6
Bacteremia	790.7	3	0.3	6	0.3
Infection and inflammatory reaction due to heart device	996.61	2	0.2	7	0.3
Infection and inflammatory reaction due to vascular device	996.62	2	0.2	6	0.3
Infection and inflammatory reaction due to urethral catheter	996.64	0	0.0	2	0.1
Infected post-surgical seroma	998.51	0	0.0	2	0.1
Other post-surgical infection	998.59	79	8.6	269	11.7
Non-healing surgical wound	998.83	0	0.0	3	0.1
Device, Implant, or Graft Complications		**8**	**0.9**	**19**	**0.8**
Mechanical complication of cardiac device, implant, graft	996.0x	0	0.0	3	0.1
Mechanical complication of other vascular device	996.1	1	0.1	1	<0.1
Complication due to heart valve prosthesis	996.71	2	0.2	3	0.1
Other complication of cardiac device, implant, graft	996.72	5	0.5	11	0.5
Adjustment of other cardiac device	V53.39	0	0.0	1	<0.1
Gastrointestinal Hemorrhage/Complications		**30**	**3.3**	**76**	**3.3**
Gastric ulcer	531.xx	0	0.0	5	0.2
Duodenal ulcer	532.xx	14	1.5	24	1.0
Peptic ulcer	533.xx	0	0.0	1	<0.1
Gastritis and duodenitis	535.xx	1	0.1	7	0.3
Vascular insufficiency of intestine (bowel infarction, ischemic colitis)	557.0, 557.9	1	0.1	6	0.3
Intestinal obstruction/paralytic ileus	560.1,560.89, 560.9	2	0.2	6	0.3
Hemorrhage of rectum and anus	569.3	1	0.1	3	0.1
Hematemesis	578.0	0	0.0	1	<0.1
Blood in stool	578.1	2	0.2	6	0.3
Hemorrhage of gastrointestinal tract, unspecified	578.9	3	0.3	11	0.5
Digestive system complications due to procedure	997.4	6	0.7	6	0.3
Genitourinary Complications		**18**	**2.0**	**44**	**1.9**
Acute renal failure/insufficiency	584.x, 593.9	14	1.5	35	1.5
Renal vascular disorder	593.81	3	0.3	3	0.1
Hematuria	599.7	0	0.0	4	0.2
Urinary complications not elsewhere classified	997.5	1	0.1	2	0.1

APPENDIX C: READMISSIONS DATA *continued*

Diagnosis	*ICD-9-CM Code*	*7-Day* N = 918 (6.0 %) #	%	*30-Day* N = 2,299 (15.0 %) #	%
Anemia/Thrombocytopenia/Anticoagulation Disorders		**14**	**1.5**	**37**	**1.6**
Iron deficiency anemias	280.x	0	0.0	1	<0.1
Other and unspecified anemias (i.e., post hemorrhagic anemia)	285.x, 285.xx	6	0.7	10	0.4
Other and unspecified coagulation defect	286.x	2	0.2	7	0.3
Purpura and other hemorrhagic conditions	287.x	1	0.1	4	0.2
Hemorrhage, unspecified	459.0	0	0.0	1	<0.1
Abnormal coagulation profile	790.92	2	0.2	10	0.4
Complications of medical care, transfusion reaction	999.8	3	0.3	4	0.2
Fluid and Electrolyte Imbalance	276.x, 276.xx	**23**	**2.5**	**59**	**2.6**
Other Surgical Complications		**71**	**7.7**	**141**	**6.1**
Cardiac complications resulting from procedure	997.1	50	5.4	89	3.9
Hemorrhage or hematoma complicating a procedure	998.1x	6	0.7	17	0.7
Accidental puncture or laceration during a procedure	998.2	1	0.1	1	<0.1
Dehiscence or rupture of operation wound	998.3x	8	0.9	20	0.9
Other procedure complications, not elsewhere classified	998.89	6	0.7	14	0.6

APPENDIX D: CANDIDATE VARIABLE DEFINITIONS

This appendix includes definitions of all variables that were tested and/or retained for the mortality, readmissions, and length of stay models. When variables were defined by the presence of ICD-9-CM codes in the discharge record, the ICD-9-CM codes are listed. Note that not every variable in this appendix was tested in every model. Moreover, when a variable had more than one overlapping definition, only one definition was used for a particular model. The columns to the right indicate which variable definitions were used in a particular group of models.

Variable Name Description	**Mortality**	**Read-missions**	**Length of Stay**
Demographic Variables			
Age in Years	X	X	X
Age # Years > 65 Number of years older than 65.	X	X	X
Female	X	X	X
Race *Category 1:* White *Category 2:* Black *Category 3:* Other/Unknown		30-day only	X
Laboratory Variables			
Albumin < 3.1[1] Laboratory value for albumin was less than or equal to 3.0 g/dL, as indicated by any of the following: • Albumin g/dL A (value in the range 1.0 – 2.4 g/dL), • Albumin g/dL B (value in the range 2.5 – 2.7g/dL), *or* • Albumin g/dL C (value in the range 2.8 – 3.0 g/dL).	X		
BUN > 40[1] Laboratory value for blood urea nitrogen (BUN) was greater than 40 mg/dL, as indicated by any of the following: • BUN mg/dL D (value in the range 41- 55 mg/dL), *or* • BUN mg/dL E (value in the range 56 – 250 mg/dL).	X		
Creatinine > 1.4[1] Laboratory value for creatinine was greater than 1.4 mg/dL, as indicated by any of the following: • Creatinine mg/dL B (value in the range: 1.5 – 2.0 mg/dL), • Creatinine mg/dL C (value in the range: 2.1 – 2.5 mg/dL), • Creatinine mg/dL D (value in the range: 2.6 – 3.0 mg/dL), *or* • Creatinine mg/dL E (value in the range: 3.1 – 25.0 mg/dL).	X		
Glucose > 165[1] Laboratory value for glucose was greater than 165 mg/dL, as indicated by either of the following: • Glucose mg/dL D (value in the range: 166 – 240 mg/dL), *or* • Glucose mg/dL E (value in the range: 241 – 2000 mg/dL).	In-hospital only		
Clinical Variables Other Than Laboratory Variables			
Acute Myocardial Infarction (AMI) AMI as indicated by code 410.x1 in the principal diagnosis position in PHC4 data.			X
AMI Other Inferior Wall Initial Episode AMI of other inferior wall, as indicated by: • 410.41 in any position in MediQual data, *or* • 410.41 in the principal diagnosis position in PHC4 data.	X		
AMI Except Other Anterior or Other Inferior Wall Any of the following codes in any position in PHC4 data: 410.01, 410.21, 410.31, 410.51, 410.61, 410.71, 410.81, or 410.91 in the principal diagnosis position in PHC4 data.	X		

[1] This variable was developed by MediQual for their CABG/valve in-hospital mortality model using the MediQual *Atlas Outcomes*® System data.

APPENDIX D: CANDIDATE VARIABLE DEFINITIONS *continued*

Variable Name Description	**Mortality**	**Read-missions**	**Length of Stay**
Anemia Any of the following codes in any position in PHC4 data: 280.0, 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, 282.41, 282.42, 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, 284.0, 284.8, 284.9, 285.0, 285.21, 285.22, 285.29, 285.8, 285.9.			X
ASA Class 5[1] High risk operation, as indicated by an anesthesia class of 5 for the first open heart procedure. This physical status classification system was created by the American Society of Anesthesiologists. Scale: 1 – 5, where 5 is the highest risk category.	X	7-day only	
ASA Emergency Flag[1] Emergency operation, as indicated by an anesthesia emergency flag for the first open heart procedure. This physical status classification system was created by the American Society of Anesthesiologists.	X		
Cachexia Any of the following codes in any position in PHC4 data: 261, 262, 263.0, 263.1, 263.2, 263.8, 263.9, 799.4, V85.0*.	X		X
CAD > 70, 5-7 Vessels Group[1] Coronary Artery Disease (CAD) with greater than 70% occlusion in 5 to 7 coronary arteries.	X		
Cancer Any of the following codes in any position in PHC4 data: 140.0 - 208.9, 230.0 - 239.9.	Operative only		X
Cardiogenic Shock, Preoperative Medical record review to determine if cardiogenic shock was present prior to CABG and/or valve surgery.	X		X
Cardiomyopathy Any of the following codes in any position in PHC4 data: 414.8, 425.1, 425.3, 425.4, 425.5, 425.8, 425.9, 429.1, 429.3.	Operative only		
Chronic Lung Disease Any of the following codes in any position in PHC4 data: 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, 518.2, 518.83.	X	X	X
Chronic Pulmonary Hypertension Any of the following codes in any position in PHC4 data: 416.0, 416.1, 416.8, 416.9.	X	X	X
Coagulopathy Any of the following codes in any position in PHC4 data: 286.0, 286.1, 286.2, 286.3, 286.4, 287.3**, 287.30*, 287.31*, 287.32*, 287.33*, 287.39*, 289.81.	X		X
Current Med Immunosuppressants[1] Based on the presence of the Current Med Immunosuppressive History KCF.	X		
Current Med Insulin[1] Based on the presence of the Current Med Insulin History KCF.	X		
Diabetes *Category 1:* No diabetes *Category 2:* Diabetes without complication was indicated by the presence of code 250.0x in any position in PHC4 data. *Category 3:* Diabetes with complication was indicated by any code in the following range in PHC4 data: 250.1x - 250.9x.		30-day only	
Diabetes with Long Term/Unspecified Complications Diabetes with long term or unspecified complications, as indicated by any of the following codes in any position in PHC4 data: 250.4x - 250.9x.		7-day only	X
Ejection Fraction[1] *Category 1:* EF > 45% was based on the presence of an ejection fraction or fractional shortening greater than 45% as a transfer, preadmission, or admission KCF. *Category 2:* 25% to 45% was based on the presence of an ejection fraction or fractional shortening greater than 25% and less than or equal to 45% as a transfer, preadmission, or admission KCF. Also included cases without an EF finding. *Category 3:* EF < 25% was based on the presence of an ejection fraction or fractional shortening less than 25% as a transfer, preadmission, or admission KCF.	X		

[1] This variable was developed by MediQual for their CABG/valve in-hospital mortality model using the MediQual *Atlas Outcomes*® System data.
* Effective Q4 2005
** Invalid after Q3 2005

APPENDIX D: CANDIDATE VARIABLE DEFINITIONS *continued*

Variable Name Description	**Mortality**	**Read-missions**	**Length of Stay**
Excision of Other Lesion/Heart Tissue, Open Approach – Same Date as Valve Surgery w/wo CABG This procedure is indicated by the presence of code 37.33 on the same date as valve surgery with or without CABG in any position in PHC4 data. If valve and CABG surgeries were performed during the same admission but on different dates the date of the valve surgery was used.	In-hospital only	X	X
Heart Failure Heart failure, as indicated by either of the following: • The presence of congestive heart failure (CHF) as a preadmission or admission KCF in MediQual data, *or* • Any of the following codes in any position in PHC4 data: 398.91, 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. *For those cases having one of the above heart failure codes and a hypertension with congestive heart failure code (402.x1, 404.x1, 404.x3) in the same record, the case was assigned to hypertension with complications.*	X	X	
Heart Failure[2] Any of the following codes in any position in PHC4 data: 398.91, 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. *For those cases having one of the above heart failure codes and a hypertension with congestive heart failure code (402.x1, 404.x1, 404.x3) in the same record, the case was assigned to hypertension with complications.*			X
History of CABG or Valve Surgery History of CABG and/or valve surgery, as indicated by any of the following: • The presence of the Previous CABG History KCF in MediQual data, *or* • Any of the following codes in the principal diagnosis position in PHC4 data: 996.02, 996.03, 996.61, 996.71, 996.72, *or* • Any of the following codes in any position in PHC4 data: V42.2, V43.3, V45.81, 414.02 - 414.05.	X		
History of CABG or Valve Surgery[2] History of CABG and/or valve surgery, as indicated by either of the following: • Any of the following codes in the principal diagnosis position in PHC4 data: 996.02, 996.03, 996.61, 996.71, 996.72, *or* • Any of the following codes in any position in PHC4 data: V42.2, V43.3, V45.81, 414.02 - 414.05.			X
History of Peripheral Vascular Disease History of peripheral vascular disease was indicated by either: • The presence of the Peripheral Vascular Disease History KCF in MediQual data, *or* • Any of the following codes in any position in PHC4 data: 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, 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, 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.	X		
History of Peripheral Vascular Disease[2] Any of the following codes in any position in PHC4 data: 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, 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, 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.		30-day only	
Hypertension with Complications Any of the following codes in any position in PHC4 data: 402.01, 402.11, 402.91, 403.01, 403.11, 403.91, 404.01, 404.11, 404.91, 404.02, 404.12, 404.92, 404.03, 404.13, 404.93, 405.01, 405.09, 405.11, 405.19, 405.91, 405.99.	X	X	X
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery An intra-aortic balloon pump inserted prior to the date of CABG/valve surgery, as indicated by the following code in any position in PHC4 data: 37.61.	X		X

[2] This variable definition does not include the MediQual KCF. The KCF was included in the MediQual Predicted Length of Stay variable.

APPENDIX D: CANDIDATE VARIABLE DEFINITIONS *continued*

Variable Name Description	**Mortality**	**Read-missions**	**Length of Stay**
Liver Disease Any of the following codes in any position in PHC4 data: 456.0, 456.20, 456.21, 571.0, 571.3, 571.40, 571.41, 571.49, 571.5, 571.6, 571.8, 571.9, 572.3, 573.3.	In-hospital only		X
MI/AMI Other Anterior Wall Myocardial infarction/acute myocardial infarction of other anterior wall, as indicated by either one of the following: • The presence of myocardial infarction as either a preadmission or admission KCF *and* the diagnosis code 410.11 in any position in MediQual data, *or* • 410.11 as the principal diagnosis code in PHC4 data.	X		
Mild Moderate or Severe AMS[1] Altered mental status is based on the presence of the following preadmission or admission KCF in MediQual data: • Mild – Disoriented, lethargy, or Glascow Coma Score from 10 – 14, • Moderate – Glascow Coma Score from 5 – 9, *or* • Severe – Coma/stupor or Glascow Coma Score < 5.	X		
Morbid Obesity Code 278.01 in any position in PHC4 data.		30-day only	
MediQual Predicted Length of Stay The predicted length of stay derived from MediQual's Predicted Length of Stay model for CABG/valve. This variable consists of demographic and clinical data including laboratory findings.		X	X
Multiple Valve Procedures Any combination of valve procedure codes (i.e., two or more codes in any position in PHC4 data): 35.20, 35.21, 35.22, 35.23, 35.24, 35.25 35.26, 35.27, 35.28, 35.10, 35.11, 35.12, 35.13, 35.14, 35.33, 35.99.	X	30-day only	X
Other CV Procedure Group Other cardiovascular procedures indicated by any of the following codes in any position: • 36.31, 36.32, 36.39, 36.91, 36.99, 37.10, 37.11, 37.32, 37.33, 38.44, 38.45, 38.46, 39.51, 39.52. in MediQual data, *or* • 35.00, 35.01, 35.02, 35.03, 35.04, 35.31, 35.32, 35.34, 35.35, 35.39, 35.50, 35.51, 35.53, 35.54, 35.60, 35.61, 35.62, 35.63, 35.70, 35.71, 35.72, 35.73, 35.81, 35.82, 35.83, 35.84, 35.91, 35.92, 35.93, 35.94, 35.95, 35.98, 36.2, 36.31, 36.32, 36.39, 36.91, 36.99, 37.10, 37.11, 37.12, 37.31, 37.32, 37.33, 37.41, 37.49, 37.51, 37.52, 37.53 in PHC4 data.	X	X	
Other Open Heart Procedure Other heart procedures, as indicated by any of the following procedure codes in any position in PHC4 data: 35.00, 35.01, 35.02, 35.03, 35.04, 35.31, 35.32, 35.34, 35.35, 35.39, 35.50, 35.51, 35.53, 35.54, 35.60, 35.61, 35.62, 35.63, 35.70, 35.71, 35.72, 35.73, 35.81, 35.82, 35.83, 35.84, 35.91, 35.92, 35.93, 35.94, 35.95, 35.98, 36.2, 36.31, 36.32, 36.39, 36.91, 36.99, 37.10, 37.11, 37.12, 37.31, 37.32, 37.33, 37.41, 37.49, 37.51, 37.52, 37.53.			X
Percent of Left Main Stenosis[1] Percent of occlusion in the left main coronary artery (continuous variable).	In-hospital only		
Procedure Group *Category 1:* CABG without valve: any of the following codes with ***no*** valve procedure codes: 36.10, 36.11, 36.12, 36.13, 36.14, 36.15, 36.16, 36.17, 36.19. *Category 2:* Valve without CABG: any of the following codes with ***no*** CABG codes: 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. *Category 3:* Valve with CABG: cases with at least one CABG code from ***and*** at least one valve code.	X	X	X
PTCA/Stent Same Day as CABG/Valve Surgery Any of the following procedure codes in any position in PHC4 data on the same date as a CABG/valve procedure: 36.01**, 36.02**, 36.05**, 36.06, 36.07, 36.09, 00.66.*			X

[1] This variable was developed by MediQual for their CABG/valve in-hospital mortality model using the MediQual *Atlas Outcomes*® System data.
* Effective Q4 2005
** Invalid after Q3 2005

APPENDIX D: CANDIDATE VARIABLE DEFINITIONS *continued*

Variable Name Description	**Mortality**	**Read-missions**	**Length of Stay**
PTCA/Stent/Tear Same Day as CABG/Valve Surgery Based on either of the following: • A CABG procedure or valve procedure performed on the same day as PTCA with the presence of "vessel tear" as either a preadmission or admission KCF in MediQual data, *or* • Any of the following procedure codes in any position in PHC4 data on the same date as a CABG/valve procedure: 36.01**, 36.02**, 36.05**, 36.06, 36.07, 36.09, 00.66.*	X	7-day only	
Renal Failure/Dialysis (category) *Category 1:* No renal failure or dialysis *Category 2:* Chronic renal failure: 585**, 585.1* - 585.9* in any position in PHC4 data. *Category 3:* Preoperative acute renal failure code 584.5 - 584.9 in any position in the PHC4 data and review of the medical record to determine if acute renal failure was present prior to the CABG/valve surgery *or* dialysis code 39.95 or 54.98 in any position prior to the date of the CABG/valve surgery.	X	30-day only	
Renal Failure/Dialysis (binary) Any of the following codes in any position in the PHC4 data: • Chronic renal failure code 585**, 585.1* - 585.9*, *or* • Preoperative acute renal failure code 584.5 - 584.9 and review of the medical record to determine if acute renal failure was present prior to the CABG/valve surgery, *or* • Dialysis code 39.95 or 54.98 prior to the date of the CABG/valve surgery.		7-day only	X
Septal Other Anomalous Repair Heart[1] Repair of septal defect in heart, as indicated by any of the following codes: 35.41, 35.42, 35.50, 35.51, 35.52, 35.53, 35.54, 35.55, 35.60, 35.61, 35.62, 35.63, 35.70, 35.71, 35.72, 35.73, 35.81, 35.82, 35.83, 35.84, 35.91, 35.92, 35.93, 35.94, 35.95, 35.98.	X		
SIRS Group[1] This variable was indicated by the presence of any two of four criteria that define SIRS (Systemic Inflammatory Response Syndrome): • Temperature > 38°C (> 100.4°F) or < 36°C (< 96.8°F) • Heart rate > 89 beats/minute • Respiration rate > 19/minute or $PaCO_2$ < 32 mmHg • White blood cell count > 12.0 K/µl or < 4.0 K/µl or > 10% bands	X		

[1] This variable was developed by MediQual for their CABG/valve in-hospital mortality model using the MediQual *Atlas Outcomes*® System data.
* Effective Q4 2005
** Invalid after Q3 2005

APPENDIX E: CANDIDATE VARIABLE DATA

Mortality Models – Candidate Variable Frequency

Variable	In-Hospital Mortality		Operative Mortality	
	#	%	#	%
Age in Years & Age # Years > 65 *(tested as continuous variables)*				
30 – 39 years	170	1.2	149	2.0
40 – 49 years	1,037	1.3	921	1.3
50 – 59 years	3,220	1.2	2,906	1.5
60 – 69 years	4,862	1.7	4,438	2.0
70 – 79 years	5,819	3.7	5,304	4.4
80 – 89 years	2,189	6.9	1,993	8.0
90 – 99 years	34	8.8	33	15.2
Albumin < 3.1				
No	16,737	2.8	15,205	3.3
Yes	594	7.7	539	7.8
AMI Other Inferior Wall Initial Episode				
No	16,905	2.9	15,355	3.4
Yes	426	5.2	389	5.9
AMI Except Other Anterior or Other Inferior Wall				
No	14,808	2.6	13,427	3.1
Yes	2,523	4.7	2,317	5.4
ASA Class 5				
No	17,237	2.8	15,660	3.3
Yes	94	25.5	84	27.4
ASA Emergency Flag				
No	16,335	2.7	14,830	3.2
Yes	996	6.8	914	7.3
BUN > 40				
No	16,753	2.7	15,211	3.2
Yes	578	10.7	533	11.8
Cachexia				
No	17,082	2.7	15,521	3.2
Yes	249	17.7	223	19.3
CAD > 70, 5-7 Vessels Grp				
No	16,533	3.0	14,998	3.5
Yes	798	2.4	746	3.4
Cancer				
No	NA	NA	15,373	3.4
Yes	NA	NA	371	5.1
Cardiogenic Shock, Preoperative				
No	17,225	2.8	15,648	3.3
Yes	106	26.4	96	25.0

NA: Not Applicable

APPENDIX E: CANDIDATE VARIABLE DATA *continued*

Variable	In-Hospital Mortality		Operative Mortality	
	#	%	#	%
Cardiomyopathy				
No	NA	NA	13,840	3.3
Yes	NA	NA	1,904	4.5
Chronic Lung Disease				
No	13,824	2.7	12,498	3.2
Yes	3,507	3.8	3,246	4.6
Chronic Pulmonary Hypertension				
No	16,249	2.8	14,780	3.4
Yes	1,082	4.2	964	5.0
Coagulopathy				
No	17,261	2.9	15,679	3.4
Yes	70	11.4	65	12.3
Creatinine > 1.4				
No	15,451	2.4	13,996	2.9
Yes	1,880	7.4	1,748	8.2
Current Med Immunosuppressants				
No	16,838	2.9	15,294	3.4
Yes	493	4.7	450	5.6
Current Med Insulin				
No	15,755	2.7	14,290	3.3
Yes	1,576	4.9	1,454	5.4
Ejection Fraction				
>45%	8,348	2.1	7,594	2.6
25%-45%	8,373	3.5	7,604	4.1
<25%	610	6.1	546	7.1
Excision of Other Lesion/Heart Tissue, Open Approach – Same Date as Valve Surgery w/wo CABG				
No	16,733	2.8	NA	NA
Yes	598	5.5	NA	NA
Female				
No	11,551	2.2	10,453	2.7
Yes	5,780	4.3	5,291	5.0
Glucose > 165				
No	13,482	2.6	NA	NA
Yes	3,849	4.2	NA	NA
Heart Failure				
No	11,771	1.4	10,851	1.8
Yes	5,560	6.1	4,893	7.1
History of CABG or Valve Surgery				
No	15,991	2.6	14,559	3.2
Yes	1,340	6.4	1,185	6.8

NA: Not Applicable

APPENDIX E: CANDIDATE VARIABLE DATA *continued*

Variable	In-Hospital Mortality		Operative Mortality	
	#	%	#	%
History of Peripheral Vascular Disease				
No	14,165	2.6	12,816	3.2
Yes	3,166	4.3	2,928	4.8
Hypertension with Complications				
No	16,343	2.6	14,829	3.0
Yes	988	9.0	915	10.3
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery				
No	16,522	2.7	14,997	3.3
Yes	809	6.8	747	7.5
Liver Disease				
No	17,235	2.9	NA	NA
Yes	96	7.3	NA	NA
MI/AMI Other Anterior Wall				
No	16,992	2.9	15,431	3.4
Yes	339	5.0	313	5.8
Mild Moderate or Severe AMS				
No	16,783	2.8	15,236	3.3
Yes	548	7.7	508	8.9
Multiple Valve Procedures				
No	16,526	2.6	15,034	3.2
Yes	805	8.8	710	9.7
Other CV Procedure Group				
No	16,004	2.6	14,545	3.2
Yes	1,327	6.3	1,199	6.9
Percent of Left Main Stenosis *(tested as a continuous variable)*				
0	12,373	3.0	NA	NA
1-10	88	0.0	NA	NA
11-20	400	4.0	NA	NA
21-30	591	2.0	NA	NA
31-40	471	1.5	NA	NA
41-50	779	3.1	NA	NA
51-60	599	2.2	NA	NA
61-70	672	2.4	NA	NA
71-80	640	1.4	NA	NA
81-90	421	4.0	NA	NA
>90	297	5.7	NA	NA
Procedure Group				
CABG without Valve	11,875	1.9	10,925	2.3
Valve without CABG	2,846	3.0	2,472	3.6
Valve with CABG	2,610	7.5	2,347	8.6

NA: Not Applicable

APPENDIX E: CANDIDATE VARIABLE DATA *continued*

Variable	In-Hospital Mortality		Operative Mortality	
	#	%	#	%
PTCA/Stent/Tear Same Day as CABG/Valve Surgery				
No	17,126	2.9	15,563	3.4
Yes	205	8.8	181	8.3
Renal Failure/Dialysis				
No	16,745	2.7	15,196	3.3
Chronic	423	7.8	393	8.4
Acute/Dialysis	163	9.8	155	11.0
Septal Other Anomalous Repair Heart				
No	17,123	2.9	15,560	3.4
Yes	208	7.7	184	8.7
SIRS Group				
No	11,530	2.3	10,388	2.7
Yes	5,801	4.2	5,356	5.0

Readmissions Models – Candidate Variable Frequency

Variable	7- & 30-Day Readmissions	7-Day Readmissions	30-Day Readmissions
	#	%	%
Age in Years & Age # Years > 65 *(tested as continuous variables)*			
30-39	22	4.1	15.0
40-49	123	4.7	13.5
50-59	340	4.7	11.8
60-69	625	5.9	14.3
70-79	821	6.5	16.1
80-89	363	7.8	19.5
90-99	5	6.7	16.7
ASA Class 5			
No	2,286	6.0	NA
Yes	13	9.7	NA
Chronic Lung Disease			
No	1,699	5.5	14.0
Yes	600	8.0	19.2
Chronic Pulmonary Hypertension			
No	2,104	5.9	14.6
Yes	195	8.3	21.1

NA: Not Applicable

APPENDIX E: CANDIDATE VARIABLE DATA *continued*

Variable	7- & 30-Day Readmissions #	7-Day Readmissions %	30-Day Readmissions %
Diabetes			
No	1,388	NA	13.8
Diabetes without Complication	698	NA	16.5
Diabetes with Complication	213	NA	21.4
Diabetes with Long Term/Unspecified Complications			
No	2,088	5.9	NA
Yes	211	8.1	NA
Excision of Other Lesion/Heart Tissue, Open Approach – Same Date as Valve Surgery w/wo CABG			
No	2,200	5.9	14.9
Yes	99	8.8	19.9
Female			
No	1,385	5.4	13.5
Yes	914	7.2	18.0
Heart Failure			
No	1,414	5.1	13.2
Yes	885	8.1	19.2
History of Peripheral Vascular Disease			
No	1,899	NA	14.5
Yes	400	NA	18.5
Hypertension with Complications			
No	2,112	5.9	14.6
Yes	187	8.1	22.4
Morbid Obesity			
No	2,142	NA	14.7
Yes	157	NA	23.0
MediQual Predicted Length of Stay *(tested as a continuous variable)*			
< 8.461 days	31	4.0	9.5
8.461 – 10.057 days	200	3.5	9.5
10.058 – 17.361 days	1,539	6.0	14.6
17.362 – 23.643 days	439	8.6	21.6
> 23.643 days	90	8.8	28.1
Multiple Valve Procedures			
No	2,152	NA	14.7
Yes	147	NA	22.5
Other CV Procedure Group			
No	2,089	5.8	14.7
Yes	210	8.0	18.6

NA: Not Applicable

APPENDIX E: CANDIDATE VARIABLE DATA *continued*

Variable	7- & 30-Day Readmissions #	7-Day Readmissions %	30-Day Readmissions %
Procedure Group			
CABG without Valve	1,455	5.5	13.6
Valve without CABG	426	6.6	17.8
Valve with CABG	418	7.8	19.2
PTCA/Stent/Tear Same Day as CABG/Valve Surgery			
No	2,267	6.0	NA
Yes	32	9.6	NA
Race			
White	2,042	NA	14.7
Black	142	NA	21.4
Other/Unknown	115	NA	14.8
Renal Failure/Dialysis			
No	2,188	NA	14.8
Chronic	75	NA	20.5
Acute/Dialysis	36	NA	25.5
Renal Failure/Dialysis (binary)			
No	2,188	5.9	NA
Yes	111	7.5	NA

Post-Surgical Length of Stay Model – Candidate Variable Frequency

Variable	Length of Stay #	Days
Acute Myocardial Infarction (AMI)		
No	13,622	7.1
Yes	3,017	7.6
Age in Years & Age # Years > 65 *(tested as continuous variables)*		
30-39 years	167	5.8
40-49 years	1,015	5.8
50-59 years	3,151	6.0
60-69 years	4,734	6.8
70-79 years	5,529	7.9
80-89 years	2,012	8.9
90-99 years	31	8.9
Anemia		
No	14,005	7.1
Yes	2,634	7.7

NA: Not Applicable

APPENDIX E: CANDIDATE VARIABLE DATA *continued*

Variable	Length of Stay	
	#	Days
Cachexia		
No	16,467	7.1
Yes	172	15.4
Cancer		
No	16,257	7.2
Yes	382	7.7
Cardiogenic Shock, Preoperative		
No	16,570	7.2
Yes	69	12.6
Chronic Lung Disease		
No	13,325	6.9
Yes	3,314	8.5
Chronic Pulmonary Hypertension		
No	15,615	7.1
Yes	1,024	8.9
Coagulopathy		
No	16,580	7.2
Yes	59	8.8
Diabetes with Long Term/Unspecified Complications		
No	15,589	7.1
Yes	1,050	8.1
Excision of Other Lesion/Heart Tissue, Open Approach – Same Date as Valve Surgery w/wo CABG		
No	16,076	7.1
Yes	563	9.7
Female		
No	11,182	6.9
Yes	5,457	7.9
Heart Failure		
No	12,623	6.4
Yes	4,016	9.9
History of CABG or Valve Surgery		
No	15,784	7.2
Yes	855	7.6
Hypertension with Complications		
No	15,760	7.0
Yes	879	10.2

NA: Not Applicable

APPENDIX E: CANDIDATE VARIABLE DATA *continued*

Variable	Length of Stay	
	#	Days
Intra-Aortic Balloon Pump (IABP) Prior to Date of CABG/Valve Surgery		
No	15,898	7.1
Yes	741	8.7
Liver Disease		
No	16,551	7.2
Yes	88	9.0
MediQual Predicted Length of Stay *(tested as a continuous variable)*		
< 8.461 days	374	5.3
8.461 – 10.057 days	2,336	5.5
10.058 – 17.361 days	11,465	7.0
17.362 – 23.643 days	2,133	9.5
> 23.643 days	331	11.8
Multiple Valve Procedures		
No	15,922	7.0
Yes	717	11.1
Other Open Heart Procedure		
No	15,424	7.1
Yes	1,215	9.0
Procedure Group		
CABG without Valve	11,525	6.5
Valve without CABG	2,727	8.0
Valve with CABG	2,387	9.9
PTCA/Stent Same Day as CABG/Valve Surgery		
No	16,513	7.2
Yes	126	8.5
Race		
White	15,024	7.1
Black	700	8.7
Other/Unknown	915	7.9
Renal Failure/Dialysis (binary)		
No	16,115	7.1
Yes	524	10.6

NA: Not Applicable

APPENDIX F: *ATLAS OUTCOMES*® APPROACH TO RISK-ADJUSTMENT

Hospitals were required to use the MediQual *Atlas Outcomes*® System to abstract patient severity information, which is an objective severity of illness grouping, and risk-adjustment system that classifies each patient's risk on admission using data known as Key Clinical Findings (KCFs). The *Atlas Outcomes*® system is based on the examination of numerous Key Clinical Findings (KCFs) such as lab test results, EKG findings, vital signs, the patient's medical history, imaging results, pathology, age, sex, and operative/endoscopy findings. Hospital personnel abstract these KCFs during specified time frames in the hospitalization. Some pre-admission data are also captured (e.g., cardiac catheterization findings), as are some history findings.

MediQual, in consultation with their Clinical Advisory Panel, designed in-hospital mortality and length of stay models focusing specifically on the patients who underwent a CABG and/or valve procedure. These models have many similarities to other disease group models used to calculate Admission Severity Groups (ASGs) in the *Atlas Outcomes*® system, though some differences were introduced to account for the unique characteristics of this population. The KCF variables were entered into algorithms that calculated the overall predicted probability of death or the predicted length of stay for patients undergoing a CABG and/or valve procedure. The predicted probability of death was derived from a logistic regression model and has a value from 0.000 to 1.000. The predicted length of stay was derived from a linear regression model and has a value greater than zero.

For PHC4's in-hospital and operative mortality models, data on the individual KCFs that were found by MediQual to be predictive of in-hospital mortality were obtained and the variables were retained in PHC4's mortality models, unless the coefficient was negative. For PHC4's readmissions models, individual KCFs from MediQual's mortality model and MediQual's predicted length of stay score were tested as candidate variables. For PHC4's post-surgical length of stay model, MediQual's predicted length of stay was tested as a candidate variable.