Coronary Artery Bypass Graft (CABG) Surgery – 2002 Data

Technical Notes

The Pennsylvania Health Care Cost Containment Council
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Attachments

Outcome Measures Reported

In-hospital Mortality.....	In-hospital mortality measures the deaths that occurred during the hospital admission in which the CABG surgery was performed. Hospitals provide information to PHC4 indicating whether the patient died during the hospital stay.
30-day Post-surgical Mortality	30-day post-surgical mortality measures the deaths that occurred within 30 days of the date of the CABG surgery. Unlike in-hospital mortality, it includes deaths regardless of "where" the patient died, i.e., it includes patients who died after being discharged from the hospital. Death certificate information was obtained from the PA Department of Health to determine whether a CABG patient died within 30 days of the CABG surgery. Upon the recommendation of the Council's Technical Advisory Group, "cause of death" was not considered in this analysis.
7-day Readmissions	Some patients are discharged from the hospital following CABG surgery and are then readmitted at a later date. This measure represents the percent of patients who were readmitted to a general acute care hospital (in Pennsylvania) within 1-7 days of being discharged from the hospital in which the CABG surgery was performed. Readmissions were counted only if the patient was readmitted for particular reasons (as indicated by the principal diagnosis of the patient during the readmission; examples include infections, other heart-related conditions, complications from the surgery, etc.). A list of the principal diagnoses used in the readmission analysis is included in Attachment B.
30-day Readmissions	Similar to 7-day readmissions, this measure represents the percent of patients who were readmitted to a general acute care hospital within 1-30 days of being discharged from the hospital in which the CABG surgery was performed. It was calculated using the same principal diagnoses that were used for 7-day readmissions.
Post-surgical Length of Stay.....	Post-surgical length of stay measures how long, on average, patients stayed in the hospital following CABG surgery.
Hospital average charge.....	The hospital charges reported are charges associated with the entire hospitalization during which the CABG surgery was performed (not just the treatment associated with CABG surgery) and 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.

With the exception of hospital average charge (which is trimmed for outliers and case-mix adjusted), each of the above measures is risk adjusted, which means that the measures take into account the patient's health condition before surgery. Some patients who undergo CABG surgery are 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 are more seriously ill or at a greater risk than others. Risk-adjusting the data is important because sicker patients might be more likely to die following CABG surgery, be readmitted, or stay in the hospital longer. Through logistic or linear regression modeling, risk factors (e.g., the age of the patient and other measures that indicate the illness level of the patient) were "tested" to determine which factors predict these particular outcomes (i.e., in-hospital mortality, 30-day post-surgical mortality, and 7-day and 30-day readmissions). For example, this process answers questions, such as, "Is the age of the patient important in predicting whether he/she will be readmitted to the hospital." One important factor is the patient's "probability of death," as calculated using MediQual® Atlas Outcomes™. This information indicates how severely ill the patient was on admission to the hospital. The "probability of death" for a patient is generated from clinical information, including lab values, in the medical record.

The following pages describe the process used in risk-adjusting each of these outcome measures.

Study Population

The CABG study population includes those patients discharged from Pennsylvania hospitals in calendar year 2002 after undergoing coronary artery bypass graft (CABG) surgery (as identified by one of the following ICD.9.CM procedure codes in the medical record):

Bypass, aortocoronary, for heart revascularization, unspecified 36.10
Bypass, aortocoronary, one coronary artery 36.11
Bypass, aortocoronary, two coronary arteries 36.12
Bypass, aortocoronary, three coronary arteries..... 36.13
Bypass, aortocoronary, four or more coronary arteries 36.14
Bypass, artery, single internal mammary, coronary..... 36.15
Bypass, artery, double internal mammary, coronary 36.16
Bypass, abdominal-coronary artery 36.17
Revascularization, with bypass anastomosis, other specified 36.19

Exclusions

Cases with the following procedure codes were not verified by hospitals and were excluded from the study population:

Procedures	ICD.9.CM Procedure Codes
Valve surgery	35.10-35.14, 35.20-35.28 or 35.99
Heart transplant	37.5
Lung transplant	33.50, 33.51, 33.52
Combined heart and lung transplant	33.6
Kidney transplant	55.61, 55.69
Liver transplant	50.51, 50.59

Additional cases were excluded from analysis as discussed in Attachment A.

In-hospital Mortality, 30-day Post-surgical Mortality, and 7-day & 30-day Readmissions

Risk-Adjustment Methodology

Data Preparation

After cases to be excluded from analysis were removed, the remaining cases were randomly split into two equal-size samples. Sample I is the development sample; Sample II is the cross validation sample. The number of relevant cases for each sample is shown below.

In-hospital mortality

	Sample I	*Sample II*	*Total*
Number of Cases	8,218	8,217	16,435
Number of In-hospital Deaths	169	158	327
Mortality Rate	2.1%	1.9%	2.0%

30-day post-surgical mortality

	Sample I	*Sample II*	*Total*
Number of Cases	7,415	7,415	14,830
Number of deaths within 30 days	185	163	348
Mortality Rate	2.5%	2.2%	2.3%

7-day readmissions

	Sample I	*Sample II*	*Total*
Number of Cases	7,270	7,269	14,539
Number of Readmissions within 7 days	395	411	806
Readmission Rate	5.4%	5.7%	5.5%

30-day readmissions

	Sample I	*Sample II*	*Total*
Number of Cases	7,270	7,269	14,539
Number of Readmissions within 30 days	938	965	1,903
Readmission Rate	12.9%	13.3%	13.1%

Building the Risk Adjustment Models

The first step in building the risk adjustment models for in-hospital mortality, 30-day post-surgical mortality, 7-day and 30-day readmissions was to identify *possible* risk-adjustment factors, that is, those factors that potentially contribute to these events. In doing so, both clinical and demographic factors identified in the literature were considered. Also considered were those factors tested in previous cardiac-related reports released by the Council – taking into account the availability and usability of the variables in its database. These possible risk-adjustment factors are called *candidate variables.* Attachment C provides data for each candidate variable.

Model Selection

Model selection identifies those candidate variables that are *statistically significant predictors* of the relevant event (in this case in-hospital mortality, 30-day post-surgical mortality, 7-day and 30-day readmissions). These significant risk factors were identified using binary logistic regression. In general, the modeling step is comprised of several sub-processes including model selection, cross validation, and calculating model adequacy measures. For the first step – model selection – a backwards stepwise logistic regression model was constructed using the cases in Sample I. All tests of significance ($p < 0.10$) were based on the likelihood ratio.

Variables Evaluated as Potential Predictors for the Mortality and Readmission Outcome Measures

	Mortality		Readmissions	
Candidate Variables	**In-hospital**	**30-day Post-surgical**	**7-day**	**30-day**
Acute Myocardial Infarction (AMI)	ns	ns	ns	ns
Age	ns	ns	ns	✓
Age Squared	✓	✓	✓	✓
CABG Severity[1]	✓	✓	ns	✓
Cancer	ns	✓	ns	ns
Cardiogenic Shock	✓	✓	ns	ns
Cardiomyopathy	ns	ns	ns	ns
Complicated Hypertension	ns	ns	ns	ns
COPD	ns	✓	ns	✓
Diabetes[2]	✓	✓	✓	✓
Dialysis	✓	✓	ns	ns
Gender	ns	ns	✓	✓
Heart Failure	✓	✓	✓	✓
Obesity[2]	✓	ns	ns	✓
Peripheral Vascular Disease	ns	ns	ns	✓
Prior CABG and/or Valve Surgery	ns	ns	ns	ns
PTCA/Stent (same day as CABG)	ns	ns	ns	ns
Race/Ethnicity	ns	ns	✓	ns
Renal Failure	ns	ns	ns	ns
Predicted Length of Stay[1]	not tested	not tested	ns	ns

✓ = significant predictor

ns = not significant

[1] = Both CABG Severity and Predicted Length of Stay are calculated using MediQual® Atlas Outcomes™ taking into account the patient's risk upon admission based on clinical data found in the medical record. See Attachment D for more information.

[2] = Although 'Diabetes' and 'Obesity' were significant predictors, these two variables were not included in the final in-hospital mortality model or the final 30-day mortality model due to their negative predictive values.

For this report, the candidate variable reflects the patient's condition during the hospital admission in which the CABG surgery was performed. For example, this table shows that having pre-operative cardiogenic shock during the hospital admission in which the CABG surgery was performed was a significant predictor of whether the patient died in the hospital or within 30 days, but it was not a significant predictor of whether the patient was readmitted within 7 or 30 days.

Cross Validation

Following model selection for in-hospital mortality, 30-day post-surgical mortality, 7-day and 30-day readmissions, the models were *cross validated* using the cases in Sample II. The first step in the cross validation process was to re-estimate the model built in the model selection process, using only the variables that were significant in Sample I, to determine which factors remain significant in Sample II.

The probability values (p-values) of those variables shown to be significant predictors of each of the four outcome measures are shown in the following table.

This table shows the variables that did not cross validate (identified as those with a p-value > 0.10 for sample II). The age-squared variable did not cross validate for in-hospital mortality. Variables that did not cross validate for 30-day post-surgical mortality were age squared and cancer. Variables that did not cross validate for 7-day readmissions include age squared and race/ethnicity. Variables that did not cross validate for 30-day readmissions include age, age squared, obesity and peripheral vascular disease. Variables that did not cross validate in Sample II were still used as risk adjustment factors for the full dataset.

Probability Values for Each *Significant* Variable

	Mortality				**Readmissions**			
Significant Predictors	**In-hospital**		**30-day**		**7-day**		**30-day**	
	Sample		Sample		Sample		Sample	
	I	II	I	II	I	II	I	II
Age	ns	–	ns	–	ns	–	0.014	0.142
Age Squared	0.080	0.411	0.005	0.163	0.026	0.864	0.015	0.122
CABG Severity	<0.001	0.001	<0.001	<0.001	ns	–	<0.001	0.021
Cancer	ns	–	0.063	0.355	ns	–	ns	–
Cardiogenic Shock	<0.001	<0.001	<0.001	<0.001	ns	–	ns	–
COPD	ns	–	0.009	0.047	ns	–	0.019	0.002
Diabetes	not tested	–	not tested	–	0.059	0.022	0.001	<0.001
Dialysis	<0.001	<0.001	<0.001	<0.001	ns	–	ns	–
Gender	ns	–	ns	–	0.029	0.014	0.001	0.002
Heart Failure	<0.001	0.003	0.072	0.035	0.017	0.001	<0.001	0.002
Obesity	not tested	–	ns	–	ns	–	0.003	0.456
Peripheral Vascular Disease	ns	–	ns	–	ns	–	0.051	0.218
Race/Ethnicity	ns	–	ns	–	0.077	0.464	ns	–

Note: A p-value of < 0.10 was used to determine the significant risk factors for this report.

Measures of Model Adequacy

For the second step in the cross validation process, the estimated coefficients from Sample I were applied to both Sample I and Sample II. The objective was to evaluate the model performance in both Sample I and Sample II. The value of ROC (Receiver Operating Characteristic) Area was considered in evaluating the model performance:

ROC Area: Using in-hospital mortality as an example, the area under the receiver operating characteristic curve measures the tendency of the estimated probabilities of death for patients in the sample that died to be ranked higher than those for patients who were discharged alive. *Range: 50% to 100%*

The values for ROC area are displayed in the table below for both Sample I and Sample II. The table also includes the results from fitting the models using all of the data.

Measure	Model Selection (*Sample I)*	Cross Validation (*Sample II)*	*All Cases*
In-hospital mortality	81.4	80.3	81.1
30-day post-surgical mortality	76.0	78.0	77.0
7-day readmissions	58.6	59.9	59.2
30-day readmissions	62.5	60.5	61.6

Coefficients & Odds Ratios

The coefficients associated with the significant risk factors and their p-values are listed on the following tables. The entire data set was used in creating the final coefficients (i.e., Sample I and Sample II were “recombined” and the coefficients were re-estimated). Accompanying these coefficients is the odds ratio for each risk factor or risk factor category. For a binary variable, this ratio is the change in the odds for a patient with the risk factor category compared to a patient without it. For example, for the outcome measure in-hospital mortality, it is the probability of dying in the hospital versus the probability of surviving the hospital stay. Odds ratios are not applicable for continuous variables (age, age-squared and CABG severity).

Coefficients and Odds Ratios for Significant Predictors

In-hospital Mortality

Significant Predictors	Coefficient	p-value	Odds Ratio
Constant	-1.8704		
Age[2]	-0.0301	0.629	Not applicable[1]
Age Squared (divided by 1,000)	0.3890	0.402	Not applicable[1]
CABG Severity	0.6087	<0.001	Not applicable[1]
Cardiogenic Shock	2.5076	<0.001	12.276
Dialysis	2.0391	<0.001	7.683
Heart Failure	0.6235	<0.001	1.865

[1] These factors were tested as continuous variables.
[2] Although age was not a significant predictor, it provided precise value to the age squared variable.

30-day Post-surgical Mortality

Significant Predictors	Coefficient	p-value	Odds Ratio
Constant	-0.6308		
Age[2]	-0.0750	0.196	Not applicable[1]
Age Squared (divided by 1,000)	0.7406	0.089	Not applicable[1]
CABG Severity	0.5066	<0.001	Not applicable[1]
Cancer	0.5807	0.044	1.787
Cardiogenic Shock	2.6126	<0.001	13.634
COPD	0.4279	0.001	1.534
Dialysis	1.6633	<0.001	5.277
Heart Failure	0.3610	0.005	1.435

[1] These factors were tested as continuous variables.
[2] Although age was not a significant predictor, it provided precise value to the age squared variable.

Coefficients and Odds Ratios for Significant Predictors

7-day Readmissions

Significant Predictors	Coefficient	p-value	Odds Ratio
Constant	-3.3733		
Age[2]	-0.00548	0.878	Not applicable[1]
Age Squared (divided by 1,000)	0.1373	0.617	Not applicable[1]
Diabetes[3]		0.001	
without complication	0.2299		1.258
with complication	0.4009		1.493
Gender	0.2544	0.001	1.290
Heart Failure	0.3617	<0.001	1.436
Race/Ethnicity[3]		0.069	
Hispanic	0.1039		1.109
Black and non-Hispanic	0.4446		1.560
Other/Unknown	-0.0898		0.914

[1] These factors were tested as continuous variables.
[2] Although age was not a significant predictor, it provided precise value to the age squared variable.
[3] "No diabetes" was used as the reference to the other categories of the diabetes variable and "white and non-Hispanic" was used as the reference to the other categories of the race/ethnicity variable; therefore, coefficients are not applicable.

30-day Readmissions

Significant Predictors	Coefficient	p-value	Odds Ratio
Constant	0.5104		
Age[2]	-0.0641	0.006	Not applicable[1]
Age Squared (divided by 1,000)	0.5054	0.006	Not applicable[1]
CABG Severity	0.1894	<0.001	Not applicable[1]
COPD	0.2494	<0.001	1.283
Diabetes[3]		<0.001	
without complication	0.2755		1.317
with complication	0.4133		1.512
Gender	0.2497	<0.001	1.284
Heart Failure	0.3107	<0.001	1.364
Obesity[3]		0.004	
Unspecified obesity	-0.1653		0.848
Morbid obesity	0.3358		1.399
Peripheral Vascular Disease	0.1939	0.026	1.214

[1] These factors were tested as continuous variables.
[2] Although age was not a significant predictor, it provided precise value to the age squared variable.
[3] "No diabetes" was used as the reference to the other categories of the diabetes variable and "no obesity" was used as the reference to the other categories of the obesity variable. Therefore, coefficients are not applicable.

Calculation of Outcome Measures

Once the significant risk factors are determined for each outcome measure (*in-hospital mortality, 30-day post-surgical mortality, 7-day and 30-day readmissions*), the statistical ratings are calculated. In doing so, actual rates are compared to expected rates to determine whether the difference is statistically significant.

Determining Actual (observed) Rates

In-hospital mortality	This rate is determined by dividing the total number of deaths that occurred in the hospital by the total number of cases.
30-day post-surgical mortality	This rate is determined by dividing the total number of deaths within 30 days of the CABG surgery date by the total number of cases.
7-day and 30-day readmissions.....	These rates are determined by dividing the total number of cases who were 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.

Determining Expected Rates

The first step in calculating the expected rates is 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 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 statistically significant clinical or demographic factor is assigned a coefficient or "weight." A factor category's weight is higher (or lower) if patients with that factor category tend to have a higher (or lower) chance of the event occurring. These weights, determined using the statewide CABG data set, were used to estimate each individual patient's probability of in-hospital death, death within 30 days, or 7-day or 30-day readmission given the risk factors of the patient.

In general the equation to calculate a patient's probability of in-hospital death is:

(constant) + (age coefficient)(age) + (age^2 coefficient)(age^2) + (risk factor category coefficients relevant to each patient)

In general the equation to calculate a patient's probability of death within 30-days is:

(constant) + (age coefficient)(age) + (age^2 coefficient)(age^2) + (risk factor category coefficients relevant to each patient)

In general the equation to calculate a patient's probability of readmission within 7 days is:

(constant) + (age coefficient)(age) + (age^2 coefficient)(age^2) +(risk factor category coefficients relevant to each patient)

In general the equation to calculate a patient's probability of readmission within 30 days is:

(constant) + (age coefficient)(age) + (age^2 coefficient)(age^2) + (risk factor category coefficients relevant to each patient)

Note: Coefficients are found in the tables on the previous pages.

The results for all patients are then summed to determine the expected number of in-hospital deaths, deaths within 30-days, and readmissions within 7-days or 30-days. This expected rate is determined by dividing the total number of expected events by the total number of cases for each measure.

The following example illustrates the calculations used in determining the statistical ratings. In-hospital mortality is used as an example. The same calculations apply to 30-day post-surgical mortality and 7 and 30-day readmissions.

Example – Calculations used in 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 number of cases treated

Expected Deaths: Sum of each patient's probability of death (PD)
Percentage: Total number of expected deaths / Total number of cases treated

To calculate a patient's probability of death:

Step 1: Calculate BX:

BX = -1.8704 (constant) + (-0.0301)(patient's age) + (0.3890)(patient's age)^2 + (risk factor coefficients relevant to each patient)

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

PD = e^{BX} / $(1 + e^{BX})$ 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 = (PD) (1-PD)

Step 2: Calculate the Standard Deviation of Mortality

SUMVAR = sum of VARPAT across all cases

Standard Deviation of Mortality = square root of SUMVAR

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

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

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

Post-surgical Length of Stay

Risk-Adjustment Methodology

Risk Adjustment Model

While *logistic* regression was used to construct the models for in-hospital mortality, 30-day post-surgical mortality, 7-day and 30-day readmission, 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.

Data Preparation

The first task in constructing the post-surgical length of stay model involved randomly splitting the data set into two, equal-size samples (after cases to be excluded were removed). One set was used as the development sample (Sample I), and the other set was used as the cross-validation sample (Sample II).

Case counts and average length of stay in days

	Sample I	*Sample II*	*Total*
Number of Cases	7,960	7,960	15,920
Average Length of Stay *(arithmetic)*	6.5	6.5	6.5
Average Length of Stay *(geometric)*	5.9	5.8	5.8

Model Selection

The model was constructed using Sample I, after a natural log transformation was done to adjust for skewness in the distribution. All tests of significance were based on general linear model F-tests. A $p < 0.10$ model was built for more liberal identification of risk factors.

Variables Evaluated as Potential Predictors of Post-surgical Length of Stay

Candidate Variables	Length of Stay
Acute Myocardial Infarction (AMI)	ns
Age	ns
Age Squared	ns
CABG Severity[1]	✓
Cancer	ns
Cardiogenic Shock	✓
Cardiomyopathy	ns
Complicated Hypertension	✓
COPD	✓
Diabetes	✓
Dialysis	ns
Gender	✓
Heart Failure	✓
Obesity	ns
Peripheral Vascular Disease	ns
Predicted Length of Stay[1]	✓
Prior CABG and/or Valve Surgery	ns
PTCA/Stent (same day as CABG)	ns
Race/Ethnicity	✓
Renal Failure	ns

✓ = Significant predictor

ns = not significant

1 = Both CABG Severity and Predicted Length of Stay are calculated using MediQual® Atlas Outcomes™ taking into account the patient's risk upon admission based on clinical data found in the medical record. See Attachment D for more information.

Cross Validation – Length of Stay

The steps in the model cross validation were similar to those used for in-hospital mortality, 30-day post-surgical mortality, 7-day and 30-day readmission. The first step in the cross validation was to re-estimate the model, using only the variables that were significant in Sample I, to determine which factors remain significant in Sample II.

Probability Values for Each Significant Variable

Significant Predictors	Length of Stay	
	Sample	
	I	II
CABG Severity	< 0.0001	< 0.0001
Cardiogenic Shock	0.0006	< 0.0001
Complicated Hypertension	0.0010	< 0.0001
COPD	< 0.0001	< 0.0001
Diabetes	0.0117	< 0.0001
Gender	0.0004	0.5969
Heart Failure	< 0.0001	< 0.0001
Predicted Length of Stay	< 0.0001	< 0.0001
Race/Ethnicity	< 0.0001	< 0.0001

Note: A p-value of 0.10 was used to determine the significant risk factors for this report.

Measure of Model Adequacy

For the second step in the cross validation process, the estimated coefficients from Sample I were applied to both Sample I and Sample II. The objective was to evaluate the model's performance in both Sample I and Sample II. R-squared was the measure considered in evaluating the model's performance.

R-squared: Coefficient of Determination (R^2) refers to the percentage of the total variability among the patients in the sample that can be explained by the estimated model involving the specified risk factors.

R-squared Values by Sample

Development	Cross Validation	All Cases
17.4%	18.8%	18.2%

Coefficients

Each category for each statistically significant clinical or demographic factor is assigned a weight or coefficient. These coefficients are used to compute each individual patient's expected post-surgical length of stay given the risk factors of the patient.

Coefficients (or "weights") for Post-surgical Length of Stay Model

Significant Predictors	Coefficient	p-value
Constant	2.867246034	
CABG Severity	0.120812899	< 0.0001
Cardiogenic Shock	0.277528171	< 0.0001
Complicated Hypertension	0.101771939	< 0.0001
COPD	0.084020074	< 0.0001
Diabetes		< 0.0001
none	- 0.061732234	
without complication	- 0.070923358	
with complication	0.000000000	
Gender	0.020721084	0.0038
Heart Failure	0.161478830	< 0.0001
Predicted Length of Stay	0.028311079	< 0.0001
Race/Ethnicity		< 0.0001
Hispanic	-0.016585428	
white/non-Hispanic	-0.104817845	
black/non-Hispanic	0.000655949	
other/unknown	0.000000000	

Calculation of Outcome Measures

Once the significant risk factors are determined, the average expected post-surgical length of stay is calculated. The calculation of the expected length of stay is discussed below (following the discussion on the actual length of stay).

Actual Length of Stay

The actual post-surgical length of stay can be derived by subtracting the CABG procedure date from the discharge date. The average post-surgical length of stay is reported as a *geometric* mean not an arithmetic mean.

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**, *not* 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. Using hospitals as an example, a hospital's expected average was determined by averaging the expected post-surgical lengths of stay for each CABG patient. The expected average was then compared to the actual average (both are geometric averages) to determine whether the actual is significantly higher or lower than expected. Post-surgical length of stay outcomes for hospitals and surgeons were evaluated in the same way.

Expected Length of Stay

Each category for each statistically significant clinical or demographic factor is assigned a weight or coefficient. Coefficients are listed in the table on the previous page. These coefficients are summed to compute each individual patient's expected length of stay given the risk factors of the patient. The coefficient for a category represents the estimated difference in mean (log) length of stay for this category versus the base category of that factor. Thus, the coefficient for the base category of a factor is always "0" (zero). When dealing with categorical variables in the length of stay model there is 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 is required at the base level for any factor because it is already accounted for in the constant. For example, a patient with diabetes (with complication) has a "0" or "baseline" coefficient; while a patient without diabetes would be adjusted *downward* by 0.061732234. *(See table on previous page)*. The order is 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 no diabetes and diabetes (with complication) would always be – 0.061732234 independent of what the specific coefficients were for each). For quantitative factors (e.g., age, age-squared and CABG severity), there is always an adjustment since the "baseline" is 0.

Risk-adjusted Length of Stay

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".

Calculations used in post-surgical length of stay analysis

Total Cases: Number of hospitalizations *after exclusions*

Actual Mean LOS: Geometric mean of the length of stay across all 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 all cases

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

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

*E***ln**LOS = (constant) + (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):

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

Note: The following calculation can be used in determining a *patient's* expected length of stay; it is not necessary, however, in determining a hospital's geometric mean of the expected length of stay.

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 length of stay (5.8 days)

ln = natural logarithm (base e)

Hospital Charge Analysis

Trimmed and case-mix adjusted average charge was reported for hospitals only.

Exclusions from Analysis

Exclusions from the charge analysis are outlined in Attachment A.

Construction of Reference Database

The patients included in the charge analysis fall into five DRG groups. It is important to note that the study population was not identified by DRG; however, all patients are included in the five groups listed below.

- Group 1: DRG 106 **–** coronary bypass with PTCA
- Group 2: DRG 107 – coronary bypass with cardiac catheterization
- Group 3: DRG 108 – other cardiothoracic procedures
- Group 4: DRG 109 – coronary bypass without cardiac catheterization
- Group 5: DRG 514, 515 – cardiac defibrillator implant with/without cardiac catheterization

Trim Methodology

Trimming methodology was used to remove outlier charge values from the study population. Identification of outliers is imperative for the elimination of extreme values that have a significant and unrepresentative impact on the mean (average).

The trimming (deleting) of individual records from the analysis was performed after all other exclusions were satisfied. If the charge on a particular record was less than the lower trim point or in excess of the upper trim point, that record was removed from the charge analyses.

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

Since charges vary dramatically among regions, upper and lower trim points were calculated for each of the five groups of patients at the regional level (The Council uses nine regional designations). For three of the groups (DRGs 106,108 and DRG 514 & 515), these nine regions were regrouped into larger areas because of the small numbers of cases in several regions.

Trim points were determined as follows:

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

Q3 = the third quartile (75^{th} 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)

Total Charges Trim Points			
	Upper Trim Point*	**Median**	**Percentage Outliers**
DRG 106			
Regions 1, 2, 3	$ 313,616	$ 84,897	2.5 %
Regions 4, 5, 6	$308,123	$ 75,825	0.0%
Regions 7, 8, 9	$523,390	$ 105,770	1.8%
DRG 107			
Region 1	$227,013	$ 62,723	1.2%
Region 2	$143,758	$ 52,838	3.8%
Region 3	$109,492	$ 51,654	1.5%
Region 4	$116,984	$ 43,044	4.5%
Region 5	$141,257	$ 52,824	2.0%
Region 6	$148,699	$ 48,810	1.3%
Region 7	$136,259	$ 51,255	1.6%
Region 8	$357,322	$ 95,022	1.8%
Region 9	$688,993	$ 147,948	0.7%
DRG 108			
Regions 1, 2, 3	$296,039	$ 82,197	2.1%
Regions 4, 5, 6	$128,847	$ 40,770	5.1%
Regions 7, 8, 9	$941,656	$ 99,413	0.0%
DRG 109			
Region 1	$217,886	$ 58,346	0.9%
Region 2	$ 84,396	$ 36,857	6.2%
Region 3	$ 89,727	$ 40,494	1.5%
Region 4	$ 75,311	$ 30,646	3.5%
Region 5	$ 99,043	$ 38,967	2.0%
Region 6	$106,275	$ 40,089	1.0%
Region 7	$ 92,020	$ 39,721	3.0%
Region 8	$284,891	$ 64,527	1.5%
Region 9	$512,821	$ 105,069	1.1%
DRG 514, 515			
Region 1, 2, 3	$477,898	$173,995	1.5%
Region 4, 5, 6	$297,736	$133,043	2.4%
Region 7, 8, 9	$1,158,136	$267,651	1.0%

* Charges of less than $10,000 were considered invalid so no lower trim point is displayed.

Case-Mix Adjustment of Average Charge

Using case-mix adjustment, a composite average charge was developed for each of the five groups of patients. The charges associated with each group are adjusted according to the number of patients and the relative cost associated with treating patients in each of the five groups.

First, regional relative weights for each of the five groups were determined. After all exclusions were satisfied and outlier trimming was performed, the relative weight for each of the five groups within each of the nine regions (or the three larger areas) was calculated using the formula:

$$\text{Relative Weight} = \frac{\text{Average Charge for each Group (either Group 1, 2, 3, 4 or 5)}}{\text{Average Charge for Groups 1, 2, 3, 4, and 5 (combined)}}$$

Next, each hospital's case-mix index was calculated.

$$\text{A Hospital's Case-mix Index} = \frac{\Sigma(n_i \times RW_i)}{\Sigma n_i}$$

where, for a hospital located in a particular region

RW_i = the regional relative weights (corresponding to each of the five groups)

n_i = the number of cases (corresponding to each of the five groups)

and Σn_i = the total number of cases for the hospital (for all of the five groups)

Finally, for each hospital the trimmed and case-mix adjusted average charge is calculated.

$$\textbf{Trimmed and Adjusted Charge} = \frac{\textbf{Average Charge for the five Groups (combined)}}{\textbf{Case-Mix Index}}$$

Average Total Charges (by DRG and Region) and Associated Relative Weights		
	Average Charge	**Relative Weight**
DRG 106		
Regions 1, 2, 3	$100,733	1.38661797
Regions 4, 5, 6	$ 93,161	1.77417661
Regions 7, 8, 9	$136,521	1.85387432
DRG 107		
Region 1	$ 70,715	0.97341333
Region 2	$ 60,446	1.16045658
Region 3	$ 53,607	1.05218934
Region 4	$ 47,105	0.89707654
Region 5	$ 56,924	1.14191037
Region 6	$ 53,200	1.05601200
Region 7	$ 55,283	0.75071247
Region 8	$110,450	1.07373393
Region 9	$192,242	1.09894340
DRG 108		
Regions 1, 2, 3	$ 89,865	1.23702175
Regions 4, 5, 6	$ 43,450	0.82747774
Regions 7, 8, 9	$172,972	2.34884444
DRG 109		
Region 1	$ 64,738	0.89114206
Region 2	$ 40,199	0.77175695
Region 3	$ 43,039	0.84475659
Region 4	$ 32,053	0.61041831
Region 5	$ 41,749	0.83749533
Region 6	$ 41,112	0.81607133
Region 7	$ 43,126	0.58561902
Region 8	$ 80,879	0.78626494
Region 9	$140,290	0.80196191
DRG 514, 515		
Region 1, 2, 3	$187,409	2.57974355
Region 4, 5, 6	$134,166	2.55508082
Region 7, 8, 9	$304,175	4.13050651

ATTACHMENT A

Cases Included / Excluded

Exclusion Criteria

Specific cases were excluded from the analysis. Standard exclusions were identified first for the in-hospital mortality analysis. Additional cases were then excluded from the analyses for the other measures in this report (30-day post-surgical mortality, 7-day readmissions, 30-day readmissions, post-surgical length of stay, and average hospital charge).

In-hospital mortality analysis	***Statewide***		
	Cases		**Mortality**
	#	**%**	**%**
Total cases *before* exclusions	17,393	100.0	2.4
Exclusions:			
Patients designated as "clinically complex" *	943	5.4	8.8
Patients who left against medical advice	8	<0.1	0.0
Patients under age 30	7	<0.1	0.0
Total exclusions	958	5.5	8.7
Total cases to be *included* in the analysis	16,435	94.5	2.0

*Clinically complex cases are those *not* in DRG 106-109, DRG 483, or DRG 514-515, cases excluded during individual case review, and cases undergoing certain procedures during the same admission as defined by one of the following procedures:

Procedure	***ICD-9-CM Codes***
lung volume reduction (performed at the same time as CABG)	*32.22*
operations on structures adjacent to heart valves	*35.31 - 35.35, 35.39*
creation of septal defect in heart	*35.42*
repair of atrial and ventricular septa	*35.50 - 35.54, 35.60 - 35.63, 35.70 - 35.73*
total repair of certain congenital cardiac anomalies	*35.81 - 35.84*
other operations on valves and septa of heart	*35.91 - 35.95, 35.98*
repair of aneurysm of coronary vessel	*36.91*
other operations on vessels of heart	*36.99*
excision of aneurysm of heart or other lesion of heart	*37.32, 37.33*
resection of abdominal aorta, thoracic vessel, abdominal arteries	*38.44 - 38.46*
clipping of aneurysm/other aneurysm repair	*39.51, 39.52*
diagnosis of constrictive pericarditis & undergoing pericardiectomy	*423.2 in combination with 37.31*
carotid endarterectomy	*38.12*

Note: See the "Study Population" section of this document for other exclusions.

30-day post-surgical mortality analysis

Statewide

	Cases		30 day post-surgical mortality
	#	%	%
Total cases before post-surgical mortality exclusions	16,435	100.0	–
Exclusions:			
Cases with invalid/inconsistent data*	57	0.3	–
Out-of-state residents**	1,548	9.4	–
Total cases excluded from 30-day post-surgical mortality analysis	1,605	9.8	–
Total cases included in 30-day post surgical mortality analysis	14,830	90.2	2.3

*Prohibited linkage of cases with death certificate information.

**Out-of-state residents were excluded because such patients could undergo CABG surgery in a Pennsylvania hospital, return to their home state and die there. We would have no death certificate data for these patients.

7-day and 30-day Readmission analysis

Statewide

	Cases		7-day Readmis-sion	30-day Readmis-sion
	#	%	%	%
Total cases *before* readmission exclusions	16,435	100.0	–	–
Exclusions:				
Patients who died during hospitalization where CABG was performed	327	2.0	–	–
Cases with invalid/inconsistent data*	63	0.4	–	–
Out-of-state residents**	1,506	9.2	–	–
Total cases *excluded* from readmission analysis	1,896	11.5	–	–
Total cases *included* in readmission analysis	14,539	88.5	5.5	13.1

*Prohibited linkage of cases to other subsequent hospital admissions

**Out-of-state residents were excluded because such patients could under CABG surgery in a Pennsylvania hospital and be readmitted to an out-of-state hospital. We would have no readmission information for these patients.

NOTE: A readmission was counted as such if the patient was hospitalized between 1 and 7 days or between 1 and 30 days after being discharged from the hospital where the CABG surgery was performed.

Post-surgical length of stay analysis

Statewide

	Cases		Average Post-surgical LOS
	#	%	days
Total cases *before* post-surgical LOS exclusions	16,435	100.0	7.1
Exclusions:			
Patients who died	327	2.0	13.2
Patients with post-surgical LOS > 30 days	177	1.1	49.3
Patients with post-surgical LOS same day or one day	11	0.1	0.9
Total *exclusions* from post-surgical LOS analysis	515	3.1	25.4
Total cases *included* in post-surgical LOS analysis	15,920	96.9	6.5

Charge analysis

Statewide

	Cases		Avg. Total Charge
	#	%	$
Total cases *before* charge exclusions	16,435	100.0	$89,622
Exclusions:			
Patients with invalid/missing charges*	28	0.2	---
Tracheostomy cases (DRG 483)	236	1.4	$452,062
Charge outliers**	287	1.7	$278,208
Total cases *excluded* from charge analysis	551	3.4	---
Total cases *included* in charge analysis	15,884	96.6	$80,984

* Invalid/missing charges including cases with no charges or charges were less than $10,000.

**Charge outliers were determined using the same "± 3.0 interquartile range" method used for other Council reports – after accounting for differences in charges by group and by region.

ATTACHMENT B

Readmission Categories

Definition - Readmissions

Readmissions were counted only if the patient was readmitted for particular reasons (as indicated by a principal diagnosis of the patient during the readmission; examples include infections, other heart-related conditions, complications from the surgery, etc). The list follows:

Diagnosis	*ICD.9.CM Code*	*7-Days N = 806 (5.5%)* #	%	*30-Days N = 1,903 (13.1%)* #	%
Cardiac Diagnoses					
Cardiac dysrhythmias post cardiac surgery		**61**	**7.6**	**152**	**8.0**
conduction disorders (i.e., av block)	426.xx	2	0.2	9	0.5
paroxysmal tachycardias	427.0, 427.1, 427.2	9	1.1	21	1.1
atrial fibrillation/flutter	427.31, 427.32	39	4.8	96	5.0
ventricular fibrillation/flutter	427.41, 427.42	0	–	2	0.1
premature beats	427.60, 427.61, 427.69	1	0.1	2	0.1
other rhythm disorders (i.e., ectopic, nodal)	427.81, 427.89	10	1.2	22	1.2
miscellaneous dysrhythmias	427.5, 427.9	0	–	0	–
Heart Failure		**142**	**17.6**	**332**	**17.4**
rheumatic heart failure	398.91	0	–	1	0.1
benign hypertensive heart disease with CHF	402.11	0	–	0	–
malignant hypertensive heart & renal disease with CHF	404.03	0	–	0	–
unspecified hypertensive heart disease with CHF	402.91	2	0.2	5	0.3
unspecified hypertensive heart & renal disease with CHF	404.91	0	–	0	–
unspecified hypertensive heart & renal disease with CHF & renal failure	404.93	1	0.1	2	0.1
congestive heart failure	428.xx	105	13.0	237	12.5
functional disturbances following cardiac surgery	429.4	34	4.2	87	4.6
cardiogenic shock	785.51	0	–	0	–
Coronary atherosclerosis / myocardial ischemia and infarction		**50**	**6.2**	**149**	**7.8**
AMI	410.x1	28	3.5	72	3.8
postmyocardial infarction syndrome	411.0	5	0.6	17	0.9
intermediate coronary syndrome (unstable angina)	411.1	0	–	1	0.1
coronary occlusion without MI	411.81	0	–	1	0.1
acute ischemic heart disease	411.89	1	0.1	1	0.1
angina pectoris	413.x	0	–	1	0.1
coronary atherosclerosis	414.0x	16	2.0	56	2.9
aneurysm of the heart	414.10, 414.11, 414.19	0	–	0	–
other forms of chronic ischemic heart disease	414.8, 414.9	0	–	0	–
Hypertension / hypotension / syncope / dizziness	401.x, 458.x, 780.2, 780.4	**24**	**3.0**	**61**	**3.2**
Artery and vein disease / embolism / thrombosis		**19**	**2.4**	**37**	**1.9**
atherosclerosis of artery, extremity	440.xx	2	0.2	10	0.5
arterial embolism and thrombosis	444.xx	3	0.4	3	0.2
phlebitis and thrombophlebitis	451.x	1	0.1	3	0.2

**NEC: not elsewhere classified*
***NOS: not otherwise specified*
An "x" indicates an additional digit is required. For example 458.x - "x" indicates a fourth digit is required; 788.2x - "x" indicates a fifth digit is required; 410.xx - "xx" indicates both a fourth and fifth digit is required.

Diagnosis	ICD.9.CM Code	7-Days N = 806 (5.5%) #	7-Days %	30-Days N = 1,903 (13.1%) #	30-Days %
peripheral vascular complications	997.2	13	1.6	19	1.0
vascular complications-vessel NEC*	997.79	0	–	1	0.1
vascular complications med care NEC*	999.2	0	–	1	0.1
Other forms of heart disease		**4**	**0.5**	**18**	**0.9**
acute pericarditis	420.xx	0	–	6	0.3
acute myocarditis	422.00, 422.91, 422.92	0	–	0	–
other diseases of pericardium (hemopericardium, restrictive)	423.x	3	0.4	11	0.6
tricuspid valve disease	397.0	1	0.1	1	0.1
Neurologic Diagnoses					
Stroke / transient cerebral ischemia		**34**	**4.2**	**63**	**3.3**
anoxic brain damage	348.1, 997.01	0	–	0	–
retinal/visual disorders	362.30 - 362.34, 368.12, 368.40	1	0.1	2	0.1
intracerebral hemorrhage	431	1	0.1	1	0.1
occlusion and stenosis of precerebral arteries	433.xx	3	0.4	9	0.5
cerebral artery thrombosis	434.xx	14	1.7	25	1.3
transient cerebral ischemia	435.x	11	1.4	20	1.1
acute, but ill-defined cerebrovascular disease (CVA)	436	1	0.1	2	0.1
iatrogenic cerebrovascular infarction or hemorrhage	997.02	3	0.4	4	0.2
Respiratory Diagnoses					
Pleurisy		**31**	**3.8**	**90**	**4.7**
pleurisy	511.0	0	–	0	–
pleural effusion / atelectasis	511.9, 518.0	24	3.0	73	3.8
hemothorax / hemopneumothorax	511.8	3	0.4	11	0.6
pneumothorax	512.x	4	0.5	6	0.3
Pulmonary edema / insufficiency		**10**	**1.2**	**17**	**0.9**
acute pulmonary edema	518.4	1	0.1	1	0.1
pulmonary insufficiency post trauma or surgery	518.5	2	0.2	2	0.1
acute respiratory failure	518.81	6	0.7	13	0.7
other pulmonary insufficiency (i.e. acute respiratory distress)	518.82	1	0.1	1	0.1
Respiratory and other chest symptoms		**45**	**5.6**	**102**	**5.4**
Tietze's disease (i.e. costochondritis)	733.6	0	–	2	0.1
respiratory and other chest symptoms (i.e. shortness of breath, chest pain)	786.x	42	5.2	96	5.0
mediastinitis	519.2	0	–	1	0.1
trachea/bronchus disease NEC* (ulcer in trachea)	519.1	2	0.2	2	0.1
tracheostomy complications	519.09	1	0.1	1	0.1
Pulmonary embolism / infarction	415.xx	**35**	**4.3**	**77**	**4.0**
Aspiration pneumonia	507.0, 997.3	**48**	**6.0**	**81**	**4.3**

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Diagnosis	ICD.9.CM Code	7-Days N = 806 (5.5%) #	7-Days %	30-Days N = 1,903 (13.1%) #	30-Days %
Other Diagnoses					
Infections		**182**	**22.6**	**468**	**24.6**
intestinal infection due to clostridium difficile	008.45	1	0.1	8	0.4
septicemia	038.xx	9	1.1	22	1.2
bacteremia	790.7	0	–	0	–
acute/subacute bacterial endocarditis	421.0, 421.9	0	–	1	0.1
bronchitis	466.0, 490	4	0.5	8	0.4
pneumonia	481, 482.xx, 485, 486	39	4.8	83	4.4
empyema	510.0, 510.9	0	–	0	–
urinary tract infection	599.0	6	0.7	16	0.8
cellulitis	681.10, 682.x	2	0.2	14	0.7
fever	780.6	5	0.6	9	0.5
infection and inflammatory reaction due to heart device	996.61	1	0.1	5	0.3
infected post-surgical seroma	998.51	1	0.1	4	0.2
infection and inflammatory reaction due to vascular device	996.62	3	0.4	6	0.3
infection and inflammatory reaction due to other device	996.69	1	0.1	2	0.1
non-healing surgical wound	998.83	0	–	4	0.2
other post-surgical infection	998.59	109	13.5	285	15.0
infection complication med care NEC*	999.3	1	0.1	1	0.1
Device, Implant, or Graft Complications		**5**	**0.6**	**12**	**0.6**
mechanical complication of cardiac device, implant, graft	996.0x	2	0.2	3	0.2
other complication of cardiac device, implant, graft	996.71, 996.72, 996.74	3	0.4	9	0.5
GI hemorrhage / complications		**24**	**3.0**	**57**	**3.0**
esophageal hemorrhage	530.82	1	0.1	1	0.1
acute gastric ulcer	531.00, 531.01, 531.20, 531.21	2	0.2	3	0.2
chronic/unspecified gastric ulcer	531.40, 531.41, 531.60, 531.61	0	–	2	0.1
acute duodenal ulcer	532.00, 532.01, 532.20, 532.21	1	0.1	3	0.2
chronic/unspecified duodenal ulcer	532.40, 532.41, 532.60, 532.61	6	0.7	17	0.9
acute peptic ulcer	533.00. 533.01, 533.20, 533.21	0	–	1	0.1
chronic/unspecified peptic ulcer	533.40. 533.41, 533.60, 533.61	0	–	0	–
acute gastritis with mention of hemorrhage	535.01	0	–	0	–
other specified gastritis with hemorrhage	535.41	0	–	0	–
vascular insufficiency of intestine (bowel infarction, ischemic colitis)	557.0, 557.9	2	0.2	5	0.3
intestinal obstruction without hernia	560.1, 560.39, 560.81, 560.89, 560.9	5	0.6	10	0.5
hemorrhage of rectum and anus	569.3	2	0.2	2	0.1
hematemesis	578.0	1	0.1	1	0.1
blood in stool	578.1	1	0.1	4	0.2
hemorrhage of gastrointestinal tract, NOS**	578.9	2	0.2	6	0.3
digestive system complications due to procedure	997.4	1	0.1	2	0.1

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Diagnosis	ICD.9.CM Code	7-Days N = 806 (5.5%) #	7-Days %	30-Days N = 1,903 (13.1%) #	30-Days %
Genitourinary complications		**4**	**0.5**	**15**	**0.8**
acute renal failure	584.x	3	0.4	13	0.7
urinary retention	788.2x	0	–	0	–
hematuria	599.7	0	–	1	0.1
urinary complications due to procedure	997.5	1	0.1	1	0.1
Anemia / thrombocytopenia		**2**	**0.2**	**9**	**0.5**
iron deficiency anemias	280.x	0	–	2	0.1
acquired hemolytic anemias	283.x	0	–	0	–
other and unspecified anemias (i.e. post hemorrhagic anemia)	285.xx	1	0.1	4	0.2
purpura and other hemorrhagic conditions (i.e. thrombocytopenia)	287.x	1	0.1	2	0.1
hemorrhage, NOS** (i.e. rupture of blood vessel)	459.0	0	–	1	0.1
hemoperitoneum (i.e. resulting from pseudoaneurysm due to IABP)	568.81	0	–	0	–
Fluid and electrolyte imbalance	276.x	**18**	**2.2**	**42**	**2.2**
Other surgical complications		**68**	**8.4**	**121**	**6.4**
disturbance of skin sensation (i.e. paresthesia, hyperesthesia)	782.0	0	–	0	–
cardiac complications resulting from procedure	997.1	41	5.1	72	3.8
hemorrhage or hematoma complicating a procedure	998.1x	8	1.0	18	0.9
dehiscence or rupture of operation wound	998.3x	15	1.9	24	1.3
foreign body left during procedure resulting in obstruction, perforation	998.4	0	–	0	–
other procedure complications NEC*	998.89	3	0.4	6	0.3
surgical complications NOS**	998.9	1	0.1	1	0.1

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***NOS: not otherwise specified*
An "x" indicates an additional digit is required. For example 458.x - "x" indicates a fourth digit is required; 788.2x - "x" indicates a fifth digit is required; 410.xx - "xx" indicates both a fourth and fifth digit is required.

ATTACHMENT C

Candidate Variables

ICD-9-CM Codes Used to Identify Mortality and Readmission Variables

Variable	ICD-9-CM Codes
Acute Myocardial Infarction (AMI)	410.x1
Cancer	140.0 - 208.9, 230.0 - 239.9
Cardiomyopathy	425.3, 425.4, 425.8, 425.9
Complicated Hypertension	402.x1, 403.x1, 404.x1, 404.x2, 404.x3, 405.xx
COPD	491.20, 491.21, 492.0, 492.8, 496, 506.4, 518.2
Diabetes	without complication – 250.0x with complication – 250.1x - 250.9x
Dialysis	39.95, 54.98, V45.1, V56.0, V56.8
Heart Failure	398.91, 428.0 - 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, only the hypertension code was used.*
Obesity	*unspecified obesity* – 278.00 *morbid obesity* – 278.01
Peripheral Vascular Disease	443.0, 443.1, 443.81, 443.89, 443.9
Prior CABG and/or Valve Surgery	V42.2, V43.3, V45.81, 414.02 - 414.06, 996.02, 996.03
PTCA/Stent (same day as CABG)	36.01, 36.02, 36.05, 36.06, 36.07, 36.09
Renal Failure	*chronic* – 585 *acute* – 584.x1 *and before surgery – using clinical information in medical record*

An 'x' indicates an additional digit is required. For example 410.x1- "x" indicates a fourth digit is required; 250.0x -'"x" indicates a fifth digit is required; 405.xx – "xx" indicates both a fourth and fifth digit is required.

Mortality — Candidate Variable Frequency and Percent Mortality

Variable and ICD.9.CM Codes	In-hospital Mortality		30-day Mortality	
	Number	*Percent*	*Number*	*Percent*
	16,435	2.0%	14,830	2.3%
Acute Myocardial Infarction (AMI)				
no	12,499	1.7%	11,309	2.0%
yes (initial episode as principal diagnosis)	3,936	2.9%	3,521	3.4%
***CABG* Severity**				
(*tested as probability of death – a continuous variable*)				
0.000 – 0.001	0	–	0	–
0.002 – 0.011	5,742	0.5%	5,183	0.8%
0.012 – 0.057	9,291	1.9%	8,381	2.3%
0.058 – 0.499	1,401	8.3%	1,266	8.8%
0.500 – 1.000	1	100%	0	–
Age & Age-Squared *(tested as continuous variables)*				
30-39 years	123	0.8%	110	0.9%
40-49 years	1,031	0.8%	927	1.1%
50-59 years	3,379	1.0%	3,037	1.2%
60-69 years	4,895	1.2%	4,409	1.5%
70-79 years	5,503	3.0%	4,971	3.3%
80-89 years	1,482	4.1%	1,355	4.9%
90-99 years	22	4.5%	21	4.8%
Average age: 66.2 (males 65.1; females 68.6)				
Cancer				
no	16,072	2.0%	14,499	2.3%
yes	363	3.0%	331	5.1%
Cardiogenic Shock				
no	16,331	1.8%	14,741	2.2%
yes (before surgery–using clinical info. in the medical record)	104	28.8%	89	32.6%
Cardiomyopathy				
no	16,024	1.9%	14,479	2.3%
yes	411	4.6%	351	4.6%
Complicated Hypertension				
no	15,820	1.8%	14,271	2.2%
yes	615	7.6%	559	7.3%
COPD				
no	13,656	1.8%	12,315	2.1%
yes	2,779	3.1%	2,515	3.8%
Diabetes				
no	10,711	2.1%	9,665	2.4%
diabetes without complication	4,714	1.8%	4,258	2.2%
diabetes with complication	1,010	2.2%	907	2.5%
Dialysis				
no	16,180	1.7%	14,603	2.1%
yes	255	21.2%	227	17.2%

Mortality — Candidate Variable Frequency and Percent Mortality

Variable and ICD.9.CM Codes	In-hospital Mortality		30-day Mortality	
	Number	*Percent*	*Number*	*Percent*
	16,435	2.0%	14,830	2.3%
Gender				
male	11,413	1.7%	10,272	2.0%
female	5,022	2.7%	4,558	3.1%
Heart Failure				
no	13,575	1.3%	12,324	1.8%
yes	2,860	5.1%	2,506	5.1%
Obesity				
no	14,491	2.1%	13,094	2.4%
unspecified obesity	1,440	0.9%	1,277	1.6%
morbid obesity	504	1.4%	459	2.2%
Peripheral Vascular Disease				
no	15,194	2.0%	13,676	2.3%
yes	1,241	1.8%	1,154	2.4%
Prior CABG and/or Valve Surgery				
no	15,638	1.9%	14,124	2.3%
yes	797	3.4%	706	3.7%
PTCA/Stent (same day as CABG)				
no	16,290	1.9%	14,697	2.3%
yes	145	9.0%	133	10.5%
Race/Ethnicity				
Hispanic	255	1.2%	237	0.8%
white/non-Hispanic	14,673	1.9%	13,376	2.3%
black/non-Hispanic	575	3.5%	531	3.4%
other/unknown	932	2.7%	686	2.8%
Renal Failure				
no	16,252	1.9%	14,661	2.3%
chronic	105	4.8%	100	4.0%
acute	78	11.5%	69	11.6%

Readmissions - Candidate Variable Frequency and Percent Readmission

Variable and ICD.9.CM Codes	7-day Readmission		30-day Readmission	
	Number	*Percent*	*Number*	*Percent*
	14,539	5.5%	14,539	13.1%
Acute Myocardial Infarction (AMI)				
no	11,117	5.5%	11,117	12.7%
yes (initial episode as principal diagnosis)	3,422	5.8%	3,422	14.2%
***CABG* Severity**				
(*tested as probability of death – a continuous variable*)				
0.000 – 0.001	0	–	0	–
0.002 – 0.011	5,155	4.3%	5,155	9.7%
0.012 – 0.057	8,225	6.0%	8,225	14.0%
0.058 – 0.499	1,159	7.7%	1,159	21.4%
0.500 – 1.000	0	–	0	–
Predicted LOS				
<2.327 days	337	3.6%	337	11.0%
2.327 – 3.463 days	2,066	3.8%	2,066	9.8%
3.464 – 6.494 days	9,988	5.7%	9,988	13.2%
6.495 – 8.723 days	1,892	6.8%	1,892	16.4%
> 8.723 days	256	5.5%	256	15.2%
Age & Age-Squared *(tested as continuous variables)*				
30-39 years	109	3.7%	109	15.6%
40-49 years	920	4.2%	920	10.5%
50-59 years	3,007	4.7%	3,007	11.8%
60-69 years	4,354	5.5%	4,354	11.9%
70-79 years	4,832	5.8%	4,832	13.9%
80-89 years	1,297	7.8%	1,297	18.8%
90-99 years	20	5.0%	20	10.0%
Average age: 66.1 (males 65.0; females 68.6)				
Cancer				
no	14,218	5.5%	14,218	13.1%
yes	321	5.3%	321	13.7%
Cardiogenic Shock				
no	14,476	5.5%	14,476	13.1%
yes (before surgery–using clinical info. in the medical record)	63	4.8%	63	15.9%
Cardiomyopathy				
no	14,205	5.6%	14,205	13.0%
yes	334	5.1%	334	15.3%
Complicated Hypertension				
no	14,023	5.5%	14,023	12.8%
yes	516	6.6%	516	20.3%
COPD				
no	12,103	5.3%	12,103	12.4%
yes	2,436	7.0%	2,436	16.4%

Readmissions - Candidate Variable Frequency and Percent Readmission

Variable and ICD.9.CM Codes	7-day Readmission		30-day Readmission	
	Number	*Percent*	*Number*	*Percent*
	14,539	5.5%	14,539	13.1%
Diabetes				
no	9,468	4.9%	9,468	11.6%
diabetes without complication	4,184	6.4%	4,184	15.2%
diabetes with complication	887	8.0%	887	19.2%
Dialysis				
no	14,358	5.5%	14,358	13.0%
yes	181	9.4%	181	21.5%
Gender				
male	10,101	4.9%	10,101	11.6%
female	4,438	6.9%	4,438	16.6%
Heart Failure				
no	12,158	5.1%	12,158	11.9%
yes	2,381	8.0%	2,381	19.3%
Obesity				
no	12,820	5.5%	12,820	13.0%
unspecified obesity	1,266	5.6%	1,266	11.5%
morbid obesity	453	6.8%	453	19.4%
Peripheral Vascular Disease				
no	13,405	5.4%	13,405	12.8%
yes	1,134	7.6%	1,134	16.8%
Prior CABG and/or Valve Surgery				
no	13,861	5.5%	13,861	13.0%
yes	678	5.6%	678	14.0%
PTCA/Stent (same day as CABG)				
no	14,418	5.5%	14,418	13.1%
yes	121	9.1%	121	16.5%
Race/Ethnicity				
Hispanic	235	6.0%	235	13.2%
white/non-Hispanic	13,124	5.4%	13,124	12.9%
black/non-Hispanic	512	8.6%	512	18.2%
other/unknown	668	4.9%	668	12.7%
Renal Failure				
no	14,383	5.5%	14,383	13.0%
chronic	95	9.5%	95	20.0%
acute	61	6.6%	61	16.4%

Post-surgical Length of Stay - Candidate Variable Frequency and Average Length of Stay

Variable and ICD.9.CM Codes	Number of Cases (statewide)	Post-surgical Length of Stay (Arithmetic average)
total	15,920	6.5%
Acute Myocardial Infarction (AMI)		
no	12,179	6.3%
yes (initial episode as principal diagnosis)	3,741	7.2%
***CABG* Severity**		
(*tested as probability of death – a continuous variable*)		
0.000 – 0.001	0	–
0.002 – 0.011	5,685	5.3%
0.012 – 0.057	9,004	6.9%
0.058 – 0.499	1,231	9.0%
0.500 – 1.000	0	–
Predicted LOS		
<2.327 days	377	5.2%
2.327 – 3.463 days	2,273	5.5%
3.464 – 6.494 days	10,992	6.4%
6.495 – 8.723 days	2,017	7.6%
> 8.723 days	261	10.7%
Age & Age-Squared *(tested as continuous variables)*		
30-39 years	121	5.2%
40-49 years	1,012	5.3%
50-59 years	3,321	5.6%
60-69 years	4,789	6.2%
70-79 years	5,260	7.2%
80-89 years	1,396	7.8%
90-99 years	21	6.9%
Average age: 66.1 (males 65.0; females 68.5)		
Cancer		
no	15,573	6.5%
yes	347	7.1%
Cardiogenic Shock		
no	15,854	6.5%
yes (before surgery–using clinical info. in the medical record).	66	12.0%
Cardiomyopathy		
no	15,532	6.5%
yes	388	7.7%
Complicated Hypertension		
no	15,377	6.4%
yes	543	8.9%
COPD		
no	13,278	6.3%
yes	2,642	7.5%

Post-surgical Length of Stay - Candidate Variable Frequency and Average Length of Stay

Variable and ICD.9.CM Codes	Number of Cases (statewide)	Post-surgical Length of Stay (Arithmetic average)
total	15,920	6.5%
Diabetes		
no	10,373	6.4%
diabetes without complication	4,579	6.5%
diabetes with complication	968	7.8%
Dialysis		
no	15,742	6.4%
yes	178	10.0%
Gender		
male	11,098	6.3%
female	4,822	7.0%
Heart Failure		
no	13,300	6.1%
yes	2,620	8.6%
Obesity		
no	14,009	6.5%
unspecified obesity	1,423	6.0%
morbid obesity	488	6.9%
Peripheral Vascular Disease		
no	14,715	6.4%
yes	1,205	7.0%
Prior CABG and/or Valve Surgery		
no	15,157	6.5%
yes	763	7.1%
PTCA/Stent (same day as CABG)		
no	15,797	6.5%
yes	123	7.8%
Race/Ethnicity		
Hispanic	249	6.7%
white/non-Hispanic	14,230	6.4%
black/non-Hispanic	547	7.0%
other/unknown	894	7.1%
Renal Failure		
no	15,763	6.5%
chronic	92	8.3%
acute	65	10.5%

ATTACHMENT D

MediQual® Atlas Outcomes™
CABG Severity
Predicted Length of Stay

Atlas Outcomes™ Approach for Risk Adjustment

Hospitals are 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). It represents a summarization of patient risk based on clinical data found in the medical record. The information used covers the first two days of the hospital stay. This system represents a summarization of patient risk/severity that includes the patient's predicted probability of death (MQPredDeath) and predicted length of stay (MQPredLOS). The MQPredDeath is derived from a logistic regression model and has a value from 0.000 to 1.000. The MQPredLOS is derived from a linear regression model and has no bounds.

The *Atlas Outcomes*™ system is based on the examination of numerous Key Clinical Findings (KCFs) such as lab tests, EKG readings, vital signs, the patient's medical history, imaging results, pathology, age, sex, and operative/endoscopy findings. Hospital personnel abstract these KCFs during specified timeframes in the hospitalization. Some pre-admission data are also captured (e.g., cardiac catheterization findings) as are some history findings. The KCF results are entered into algorithms that calculate the overall predicted probability of death or the predicted length of stay.

For this project, MediQual, in consultation with their Clinical Advisory Panel, designed a mortality model focusing specifically on the CABG population. This model has many similarities to other disease group models used to calculate Admission Severity Groups (ASGs) in the Atlas system, though some differences were introduced to account for the unique characteristics of this population.

Like other MediQual clinical models, the CABG model uses Key Clinical Findings (KCFs), history findings, and information from the Uniform Hospital Discharge Data Set to predict a probability of in-hospital mortality. Normally, KCFs would be included in the predictions if they were collected on the first or second day; but for this model, KCFs collected on the second day for patients receiving CABG on the first day were not included. Furthermore, new variables were defined from other Atlas data specifically for use in this model, as suggested and defined by their Clinical Advisory Panel.

The results of this model were predicted probabilities of in-hospital mortality for each of the reported patients receiving CABG in 2002. PHC4 used the probabilities of in-hospital mortality, along with other patient risk factors, to risk-adjust the hospital- and physician-specific outcomes printed in the 2002 CABG Report.