TECHNICAL NOTES

for Cardiac Procedures Report

June 2026

Pennsylvania Health Care Cost Containment Council

Report Period: January 1, 2023 through December 31, 2024

225 Market Street, Suite 400, Harrisburg, PA 17101
Phone: 717-232-6787
www.phc4.org

Barry D. Buckingham, Executive Director

TABLE OF CONTENTS

OVERVIEW OF THE CARDIAC PROCEDURES REPORT 4
Procedures and Measures Reported in the Hospital Results 4
Procedures and Measures Reported in the Volume Results 5
DATA COLLECTION AND VERIFICATION 6
Handling of Anomalous Laboratory Test Results 6
HOSPITAL RESULTS SECTION 7
Study Population 7
Inclusion Criteria 7
General Exclusion Criteria 7
Measure-Specific Exclusions 7
Overview of Measures Reported 8
Number of Cases 8
Measures with Risk-Adjusted Ratings 8
Case-Mix Adjusted Average Hospital Charge 9
Average Medicare Payment 9
Risk-Adjustment and Statistical Ratings 10
Model Development 10
Determining Expected (Predicted) Value at the Patient Level 12
Determining Actual and Expected (Predicted) Values at the Hospital Level 12
Determining Statistical Ratings 14
Assignment of Statistical Ratings 15
Case-Mix Adjustment and Average Hospital Charge 16
Trim Methodology 16
Determining Actual Charges 16
Determining Expected Charges 16
Determining Case-Mix Adjusted Charges 17
VOLUME RESULTS SECTION 18
Study Population 18
Inclusion Criteria 18
Exclusion Criteria 18
Overview of Measures Reported 19
DATA TABLES 20
Table 1. Hospital Results – Statewide Utilization and Outcome Data, by Procedure 20
Table 2. Hospital Results – Exclusions from Analyses, by Procedure and Measure 21
Table 3. Volume Results – Exclusions from Analyses, by Procedure 24

APPENDICES

Appendix A. Definitions – Hospital Results A-1
Appendix B. Definitions – Volume Results A-2
Appendix C. Valid Discharge Status Codes A-3
Appendix D. Example of Logistic Regression A-4
Appendix E. Example of Linear Regression A-5
Appendix F. Example of Case-Mix Adjustment A-6

OVERVIEW OF THE CARDIAC PROCEDURES REPORT

The Technical Notes serve as a technical supplement to the Pennsylvania Health Care Cost Containment Council's (PHC4) *Cardiac Procedures Report*. This document describes the methodology and development of the report and provides data on statewide results and cases excluded from analyses. The methodology described in this document was developed to account for the differences among individual patients that had the potential to influence the outcomes of the cardiac procedures reported in the **Hospital Results** section of the report.

Inpatient acute care hospitalizations are defined using ICD-10-CM/PCS (International Classification of Diseases, Tenth Revision, Clinical Modification/Procedure Coding System) diagnosis and procedure codes, and MS-DRGs (Medicare Severity Diagnosis-Related Groups). Outpatient encounters are defined using CPT-4 (Current Procedural Technology, Fourth Edition) procedure codes and HCPCS (Healthcare Common Procedure Coding System) Level II procedure codes, as well as billing revenue codes. See Appendix A for the definitions used in the **Hospital Results** section and see Appendix B for the definitions used in the **Volume Results** section.

Procedures and Measures Reported in the Hospital Results

The procedures and measures outlined below are reported in the **Hospital Results** section of the report for acute care hospitals that typically perform these procedures on adults ages 18 years and older.[1] In addition to the measures listed below, the *number of cases* (after exclusions) is reported. Statewide utilization and outcome data reported in the **Hospital Results** section are displayed in Table 1.

Procedures included in the **Hospital Results** section of the report:

- Coronary Artery Bypass Graft (CABG)[2]
- Percutaneous Coronary Intervention (PCI) for a Heart Attack
- Percutaneous Coronary Intervention (PCI) without a Heart Attack
- Surgical Aortic Valve Replacement (SAVR)[3]
- Surgical Aortic Valve Replacement (SAVR) with Coronary Artery Bypass Graft (CABG)[4]
- Transcatheter Aortic Valve Replacement (TAVR)

Outcome measures displayed in the **Hospital Results** section when a hospital has five or more cases:

- Risk-adjusted mortality rating (*all procedure groups except TAVR*)
- Risk-adjusted 7-day readmission rating
- Risk-adjusted 30-day readmission rating
- Risk-adjusted 90-day readmission rating
- Risk-adjusted extended postoperative length of stay rating
- Average hospital charge (case-mix adjusted)

[1] Results are not displayed for hospitals that closed or merged with other facilities as of the report preparation date.
[2] CABG procedures performed without a valve procedure during the same hospitalization.
[3] SAVR procedures performed without a CABG or other heart valve procedure during the same hospitalization.
[4] SAVR with CABG is defined as a SAVR procedure and a CABG procedure performed on the same calendar date.

Procedures and Measures Reported in the Volume Results

The **Volume Results** section of the *Cardiac Procedures Report* displays the total number of cases for procedures performed on adults ages 18 years and older treated in Pennsylvania inpatient acute care hospitals, hospital outpatient departments and ambulatory surgery centers (ASCs).[1] The total number of cases for hospitals in the **Volume Results** section is often higher than the "Number of Cases" displayed in the **Hospital Results** section of the report, where cases are limited to only those included in the hospital-specific outcome measures. In general, information about the overall total number of cases performed at a facility reflects the degree of experience a facility has in caring for patients who undergo the given procedure. Additionally, higher volume has been associated with improved patient outcomes.

Some cardiac procedures are increasingly performed in hospital outpatient departments and ASCs (collectively referred to as outpatient cases). For these procedures, the total number of cases performed in both inpatient and outpatient locations are displayed separately, to show the variations in treatment patterns across care settings. These differences may reflect patient-surgeon partnership decisions and efforts to save costs.

Procedures included in the **Volume Results** section of the report:

- Cardiac Ablation
- Cardioversion
- Coronary Artery Bypass Graft
- Defibrillator Implantation
- Left Atrial Appendage Closure
- Mitral Valve Procedure
- Pacemaker Implantation
- Percutaneous Coronary Intervention
- Surgical Aortic Valve Replacement
- Transcatheter Aortic Valve Replacement
- Tricuspid Valve Procedure

Measures are displayed in the **Volume Results** section of the report:

- Total number of cases
- Total number of inpatient and outpatient cases (*select procedure groups*)

[1] Total number of cases are not displayed for facilities that closed or merged with other facilities as of the report preparation date.

DATA COLLECTION AND VERIFICATION

The data for the *Cardiac Procedures Report*, obtained from the inpatient UB-04 (Uniform Billing) form, was submitted electronically to PHC4 by Pennsylvania facilities that performed the cardiac procedures in the report on adults (18 years and older). Federal hospitals were not included. The claims data included demographic information; hospital charges; ICD-10-CM/PCS (International Classification of Diseases, Tenth Revision, Clinical Modification/Procedure Coding System) diagnosis and procedure codes; CPT-4 (Current Procedural Technology, Fourth Edition); and HCPCS (Healthcare Common Procedure Coding System) Level II procedure codes.

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

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

Handling of Anomalous Laboratory Test Results

Risk adjustment relied on the submission of valid and accurate laboratory test data. As noted, hospitals were given the opportunity to correct data anomalies (laboratory test results that were so unreasonably high or low that it was most plausibly representative of a data error). Hospitals were notified of anomalous laboratory data submissions via specific feedback reports provided on a quarterly basis. Since anomalous data that was not corrected had the potential to inaccurately skew all hospitals' final statistical ratings, such extreme values were replaced with default (typical) values when building risk-adjustment models. In effect, such laboratory test results were treated as if they were missing, in which neither penalty nor credit relative to the implicated data was applied in the calculation of a patient's risk.

HOSPITAL RESULTS SECTION

Study Population

The study population for each procedure reported in the **Hospital Results** section of the report is designed to represent a clinically cohesive group of patients. See Appendix A for ICD-10-CM/PCS diagnosis and procedure codes, Medicare Severity Diagnosis-Related Groups (MS-DRGs), and Major Diagnostic Categories (MDC) associated with each study population.

Inclusion Criteria

The study populations included inpatient acute care records for adults (18 years and older) discharged from Pennsylvania acute care hospitals during the defined report period with an ICD-10-PCS procedure code in either the principal or secondary procedure code positions and an ICD-10-CM diagnosis code, where applicable, in the discharge record.

General Exclusion Criteria

The number of cases included in any single type of analysis varied because each reported measure had its own unique set of exclusion criteria (see "Measure-Specific Exclusions" section). However, the following types of records were excluded from all measures for all reported procedures.

- Records with errors (e.g., systematic errors in coding of essential data fields such as dates, charges, etc.)
- Duplicate records
- Records with discharge date not in study period
- Records representing an inpatient rehabilitation hospitalization (not acute care) defined by rehabilitation revenue codes 0024, 0118, 0128, 0138, 0148 or 0158
- Non-adult records (< 18 years) or records with invalid age (e.g., records that did not have the necessary data for the calculation of age or for which age was > 124 years)
- ICD-10-CM/PCS code-based exclusions[1] (see Appendix A)
- Records not in MDC/MS-DRG of interest (records not assigned to MDC/MS-DRG specified in Appendix A)
- Records with missing or invalid discharge status (see Appendix C for valid discharge status codes)
- Patients who left against medical advice (records with a discharge status code 07)
- Patients transferred to acute care facilities (records with a discharge status code 02, 43, 63, 66, 82, 88, 91, or 94)

Measure-Specific Exclusions

In addition to the cases excluded from the general study population (see "General Exclusion Criteria" section), individual hospitalizations were excluded from outcome analyses when the data in the record was insufficient or inappropriate to the measure of interest. For example, patients who died were excluded from the readmission analysis but not the mortality analysis. See Table 2 for the exclusions applied for each measure and the number of cases excluded.

[1] The exclusion definition is based, in large part, on the Centers for Medicare and Medicaid Services cohort exclusion definition used in the "2025 Procedure-Specific Readmission Measures Updates and Specifications Report (Isolated Coronary Artery Bypass Graft [CABG] Surgery) – Version 12.0", April 2025. Available at https://qualitynet.cms.gov/inpatient/measures/readmission/methodology.

Overview of Measures Reported

Number of Cases

For each procedure included in the **Hospital Results** section of the report, the number of acute care hospitalizations for patients 18 years and older, after exclusions, is reported. If two procedures from the same procedure group were performed during the same hospitalization, the case was only counted once. Note that because of the excluded cases, the number of cases reported in this section of the report is typically lower than the "Total Number of Cases" displayed in the **Volume Results** section of the report.

Measures with Risk-Adjusted Ratings

Risk-adjusted ratings are reported for mortality, readmission and extended postoperative length of stay measures. The rating identifies whether the hospital's observed value of a given outcome was significantly higher than, significantly lower than, or not significantly different than expected based on patient risk factors (see "Risk Adjustment and Statistical Ratings" for methodology details and Appendix D and E for examples). Ratings are reported for hospitals with five or more cases in the analysis.

Mortality (all procedure groups except TAVR)

The in-hospital mortality analysis included patients 18 years and older who died during the hospital stay. The mortalities were identified in the patient discharge record as a discharge status of "20" (see Appendix C). The rating identifies whether the hospital's observed mortality rate is significantly higher than, significantly lower than, or not significantly different than expected based on patient risk factors.

Readmission

A hospital readmission is defined as an acute care unplanned rehospitalization to a Pennsylvania acute care hospital within 7 days, 30 days or 90 days from the date of discharge of the original hospitalization. Planned readmissions are identified using the Centers for Medicare and Medicaid Services' (CMS) planned readmission algorithm[1], which distinguishes readmissions that are typically planned from those that are unplanned. Readmissions that are identified as planned are not counted in the analysis. This rating indicates whether the hospital's observed 7-, 30-, or 90-day unplanned readmission rate is significantly higher than, significantly lower than, or not significantly different than expected.

Readmissions for inpatient rehabilitation services (identified by revenue codes 0024, 0118, 0128, 0138, 0148, or 0158), mental health (MDC 19) or alcohol/drug disorders (MDC 20) are not counted. However, a subsequent acute care readmission within the 7-, 30-, or 90-day timeframe would be counted. Readmissions for patients diagnosed with COVID-19 present on admission (ICD-10-CM diagnosis code U07.1 in any position) are not eligible. Same-day readmissions are included only if the original hospitalization resulted in a discharge to home (records with a discharge status code of 01, 06, 21, 81, 86, or 87; see Appendix C for valid discharge status codes).

Extended Postoperative Length of Stay

In general terms, an extended postoperative length of stay (PLOS) identifies that the actual length of time a patient remains in the hospital following the procedure is significantly longer than what would be

[1] The planned readmission algorithm (version 4.0) is a component of the Centers for Medicare and Medicaid Services "2025 Procedure-Specific Readmission Measures Updates and Specifications Report (Isolated Coronary Artery Bypass Graft [CABG] Surgery) – Version 12.0", April 2025. Available at https://qualitynet.cms.gov/inpatient/measures/readmission/methodology.

expected, after accounting for patient risk. The development of this measure was guided, in part, by the approach used by Michael Pine and Associates.[1]

Details for determining the patient's actual PLOS, expected (predicted) PLOS, and whether the hospital stay should be counted as an extended PLOS are outlined below (see Appendix E for an example):

- The actual PLOS (in days) was calculated as the discharge date minus the date the procedure of interest was performed. Patients discharged on the same day the procedure was performed were assigned a PLOS (in days) of 0.5.
- The expected PLOS was determined using the risk-adjustment techniques described under "Model Development" and "Determining Expected Value at the Patient Level" in the "Risk-Adjustment and Statistical Ratings" section.
- A natural log transformation of each PLOS (actual and expected values) was performed to account for skewness in the PLOS distribution.
- An extended PLOS was identified when the difference between the actual and expected log transformed PLOS values—the residual log PLOS—for a particular patient was significantly higher than the average residual log PLOS for all patients in the analysis. In statistical terms, an extended PLOS is identified when the residual log transformed PLOS is greater than two standard deviations above the average residual log transformed PLOS for a given procedure.

Case-Mix Adjusted Average Hospital Charge

The hospital charge is the total amount charged to the patient for the entire hospitalization during which the procedure was performed. It does not include professional fees (e.g., physician fees) or other additional post-discharge costs, such as rehabilitation treatment, long-term care and/or home health care. The average charges reported were trimmed and case-mix adjusted as described in the "Case-Mix Adjustment and Average Hospital Charge" section. Average charges are reported for each hospital with five or more cases.

Average Medicare Payment

The statewide average payment is reported for Medicare fee-for-service (FFS) patients (Pennsylvania residents only). Claim payment amounts were obtained from the Centers for Medicare and Medicaid Services (CMS) and matched to cases meeting the study population criteria for a given procedure. The payment data displayed in this report corresponds to hospitalizations from calendar years 2023 and 2024. Patient liabilities (e.g., coinsurance and deductible dollar amounts) and payments from Medicare Advantage plans (e.g., Medicare HMOs) were not included.

For each procedure, the overall statewide average payment is reported by MS-DRG to account for variations in case mix. The number of cases included in the average payment is also displayed. Average payments are reported at the statewide level only and are displayed for MS-DRGs with 11 or more cases.

[1] Fry DE, Pine M, Jones BL, Meinban RJ. Adverse outcomes in surgery: redefinition of postoperative complications. *The American Journal of Surgery.* 2009;197:479-484.

Risk-Adjustment and Statistical Ratings

In order to report fair comparisons among hospitals for a given procedure and measure, regression techniques were used to construct “risk models” 1) for predicting the risk of an event occurring (e.g., mortality and readmission), or 2) for the extended postoperative length of stay (PLOS) measure, predicting the log transformed PLOS. Each model was a mathematical formula used to ultimately predict a patient’s probability of the event occurring or log PLOS based on relevant risk factors. Cases with these risk factors were given more “credit” in the calculation, leading to a higher predicted probability of the event or, in effect, a longer PLOS. The ratings indicate whether the hospital’s event rates were within the expected range, or higher or lower than the expected range, after taking into account the risk factors that were included in the risk-adjustment models.

Model Development

The first step in building the risk adjustment models was to prepare a reference database. UB-04 claims data and laboratory test results from adult (18 years and older) discharges from Pennsylvania acute care hospitals were used. The reference database and measure-specific models were based on three years of data or more (after exclusions) depending on the procedure and measure being modeled.

Identifying Potential Risk Factors

The next step in building the models was to identify risk factors that potentially contributed to the event or outcome (i.e., mortality, readmission or PLOS). These factors were identified through their importance in past models, review of scientific literature and consideration of high-risk populations. Types of risk factors included were patient characteristics, laboratory test results, diagnoses and procedures identified by ICD-10-CM/PCS codes, socioeconomic factors, and other UB-04-derived factors.

Using the reference database, potential risk factors were subject to univariate analysis to determine which, because of their potential to predict the outcome of interest, should be tested for inclusion in the model for a given procedure and measure. Variables were constructed and analyzed as linear (continuous), categorical and binary as appropriate. For some factors, multiple forms of variable designs were analyzed to determine which approach best fit the data. For example, patient age was tested as a linear or linear spline with up to two knots to determine which approach best fit the data.

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

- For variables with continuous data (e.g., laboratory test results) one category represented “typical” results with additional categories representative of abnormal results generally associated with increased risk. (In the final model, all records in a specified abnormal category would receive the same amount of credit, regardless of the value within the category.) Records with missing values were combined with records in the typical category.
- For ICD-10-CM/PCS code-based categorical variables, one category represented the absence of the risk factor and additional categories represented the presence of diagnosis or procedure codes indicating increased risk for that particular condition (e.g., no cancer, primary cancer and metastatic cancer).

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

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

To avoid developing models that were "overfitted" (i.e., unnecessarily complex models with factors that may be insignificant when applied to a different dataset), a statistical criterion called the Schwarz criterion was used. This application avoided the problem of overfitting by including a penalty value for each factor as it was added to the model. In this way, the best end point for the model build (i.e., the point in which no more factors should be added to the model) could be determined. Exceptions were made to the Schwarz criterion when a variable had particular relevance to the outcome.

Each procedure and measure combination was modeled separately. Binary logistic regression was used in the analysis of the mortality and readmission measures. Linear regression was used for the extended PLOS analysis.

Risk Factor Selection

Risk factors selected for testing were added to the model in the following order: 1) patient characteristics (patient age and sex), 2) laboratory test results, 3) ICD-10-CM/PCS code-based variables, then 4) other UB-04-derived data elements (e.g., race/ethnicity, socioeconomic status, insurance type). All factors within a risk factor type were evaluated before considering factors from the next type.

Risk factors were considered statistically significant in a model if they met the $p<0.10$ significance criterion and the Schwartz criterion and indicated an increase in the risk of the event. However, risk factors were evaluated for relevance by considering both mathematical (statistical significance) and clinical perspectives (clinical importance).

Bootstrap Validation

Once the model variables were chosen, the bootstrap technique was used to identify and eliminate factors that were unstable and unlikely to predict the same level of risk when applied to other (future) datasets. Using this technique, two hundred fifty sample datasets were randomly generated from the reference database. Records were allowed to appear multiple times in the sample datasets if they were selected repeatedly. The prepared model was then fit to each sample dataset to determine the percent of sample models in which each factor maintained significance ($p<0.10$). Risk factors at or above a 75% cutoff and those with particular clinical relevance to the outcome (even if below the 75% cutoff) were retained in the final model. This same approach was used to eliminate any factor that did not have a consistently expected direction of the numeric value/coefficient in at least 75% of the sample models.

Finally, factors in the model were investigated to be sure that they were not overly influenced by the effects of a few hospitals. This could be a special concern for factors that may be concentrated in a few

hospitals. A hierarchical regression model was run with a nested random intercept unique for each hospital to assess the power of the factors after accounting for hospital differences. Factors no longer significant or with a changed sign in this hierarchical regression model were eliminated.

Determining Expected (Predicted) Value at the Patient Level

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

$$\beta X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots \beta_n X_n$$

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

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

Using logistic regression modeling, the predicted value for a patient's probability of the event (i.e., mortality or readmission) occurring was calculated as:

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

where $e \approx 2.7182818285$

Using linear regression modeling, a patient's predicted log transformed PLOS was calculated as βX. This value was then used in calculations to identify hospitalizations with an extended PLOS as described in the "Measures Reported" section.

To account for changes in the statewide rates over time, the intercept (β_0) of the model was adjusted so that the statewide expected rate, or average log transformed PLOS, for the current study period was equal to the actual statewide value for this same period.

See Appendix D for an example of logistic regression. See Appendix E for an example of linear regression and the calculation to determine if a hospitalization had an extended PLOS.

Determining Actual and Expected (Predicted) Values at the Hospital Level

Separate analyses were performed to determine, for each hospital, the actual and expected percent of hospitalizations with a given outcome. Significance tests were conducted to determine whether the difference between a hospital's actual and expected values was too large to be attributed solely to chance. These results were displayed as ratings.

Determining Actual (Observed) Values

Outcome Percent	This percent was determined by dividing the number of hospitalizations with an event by the number of hospitalizations in the analysis for a given procedure.

The actual value was calculated for each procedure and outcome combination as shown below:

CABG	Mortality percent
	7-day readmission percent
	30-day readmission percent
	90-day readmission percent
	Extended postoperative length of stay percent
PCI for a Heart Attack	Mortality percent
	7-day readmission percent
	30-day readmission percent
	90-day readmission percent
	Extended postoperative length of stay percent
PCI without a Heart Attack	Mortality percent
	7-day readmission percent
	30-day readmission percent
	90-day readmission percent
	Extended postoperative length of stay percent
SAVR	Mortality percent
	7-day readmission percent
	30-day readmission percent
	90-day readmission percent
	Extended postoperative length of stay percent
SAVR with CABG	Mortality percent
	7-day readmission percent
	30-day readmission percent
	90-day readmission percent
	Extended postoperative length of stay percent
TAVR	7-day readmission percent
	30-day readmission percent
	90-day readmission percent
	Extended postoperative length of stay percent

Determining Expected (Predicted) Values

For the mortality and readmission outcomes, the expected value for a particular hospital was calculated as the average of the predicted probabilities for each patient (i.e., hospitalization) in the analysis. This was done to adjust for the risk inherent to each particular hospital's patient population.

For the extended PLOS outcome, the expected value for a particular hospital was the percentage of hospitalizations statewide with an extended PLOS.

Determining Statistical Ratings

Significance tests (using the binomial distribution, see below) were performed for each outcome measure. To account for random variation, statistical evaluation was used to determine whether the difference between a hospital's observed and expected values was too large to be attributed solely to chance.

Binomial Distribution

The use of the binomial distribution required the following assumptions:

- Each observation included in the study had one of two observable events (e.g., readmission vs. no readmission). In other words, the response was dichotomous.
- The probability of the event (i.e., mortality or readmission) for each observation studied was equal to the probability provided by the associated logistic risk model. For extended PLOS, it is assumed the probability of an extended PLOS occurring is equal to the statewide extended PLOS rate.
- The result for any one observation in the analyses had no impact on the result of another observation. In other words, the observations were independent.

The probability distribution for a specific hospital's outcome in one area of analysis was based on the hospital's predicted or expected values. Using the probability distribution, a p-value was calculated for each observed value. This p-value was the probability, or likelihood, that the value could have occurred by chance. If it was very unlikely ($p<0.05$; see "Inferential Error" section below) that the observed or actual value could have occurred only by chance, it was concluded that the observed value was "significantly different" from the expected value.

Calculation of p-values

The binomial distribution defined a probability of each potential outcome (e.g., the probability of observing exactly 3 deaths out of 40) according to the binomial formula:

$$P(a) = \left[\frac{N!}{a!(N-a)!}\right] p^a (1-p)^{N-a}$$

where:

a — was the number of events (e.g., mortalities) that were observed (i.e., a = 1 mortality, a = 2 mortalities, etc.) in N hospitalizations. The value of "a" ranged from 0 through N (in other words, $0 \le a \le N$).

P(a) — was the probability that exactly "a" events would be observed.

N — was the number of hospitalizations for a particular hospital.

p — was the overall expected rate (e.g., expected percent mortality) for a particular hospital.

The rating process evaluated both fewer than expected as well as greater than expected mortalities. Thus, a two-tailed test was used. In the example above (3 deaths out of 40), the probability associated with the left-hand tail was the sum of the probability for 0, 1, 2, or 3 deaths out of 40. The probability of the right-hand tail was the sum of the probabilities at the upper end of the range (40, 39, 38…) until that sum was as close as possible to (but still less than) the probability associated with the left-hand tail. The two-tailed p-value was the sum of the probability of the left-hand and right-hand tails.

The two-tailed p-value was calculated for each hospital.

Inferential Error

A type of inferential error that can be made in statistics is called a Type I error or "false positive." The probability of committing a Type I error is equal to the level of significance established by the researcher. For the current analyses, the level of significance was set to 0.05.

In the context of the *Cardiac Procedures Report*, a Type I error would have occurred when the difference between the actual mortality percent and the expected mortality percent was declared statistically significant, when in fact, the difference was due to chance. That is, the hospital was declared to be statistically higher or lower than expected when in reality the hospital's level of performance was comparable to its expected performance, as determined by its risk profile. Since the level of significance was set to 0.05, there was a 5% chance (or 1 in 20) of committing this type of error.

Assignment of Statistical Ratings

A statistical rating of higher than expected or lower than expected was assigned to each hospital if the difference between what was observed and what was expected was statistically significant (p-value <0.05). The p-value, calculated in terms of a "two-tailed" test, was compared to the level of significance.

For example, in determining the readmission rating for each hospital:

- If the calculated p-value was less than 0.05, then the conclusion was made that the difference between what was expected and what was observed was statistically significant.
    - If the actual percent was less than expected, the hospital was assigned the symbol "○" (as shown in the *Cardiac Procedures Report*) to indicate that the readmission percent was significantly less than expected.
    - If the actual percent was higher than expected, the hospital was assigned the symbol "●" (as shown in the *Cardiac Procedures Report*) to indicate that the readmission percent was significantly greater than expected.
- If the calculated p-value was greater than or equal to 0.05, then the conclusion was made that the difference between the expected and the actual readmission percent was not statistically significant. It cannot be concluded that the actual percent for that particular hospital was different from the expected percent derived from the particular hospital's risk profile. In this case the hospital was assigned the symbol "⊙" (as shown in the *Cardiac Procedures Report*).

Case-Mix Adjustment and Average Hospital Charge

Hospital charges were adjusted separately for each procedure in the report to account for differences in the charges across Pennsylvania geographical regions and hospital variation in the mix of cases across MS-DRGs for a given procedure. This adjustment was made at the level of the nine PA regions (see Appendix F for regions by county).

Cases from PA region/MS-DRG group combinations with low volume (< 20 cases after trimming of outliers) were excluded from the analysis.

Trim Methodology

Trimming was used to remove outlier charges from the study population for a given procedure in order to eliminate extreme values that may have a significant and unrepresentative impact on the average. Since charges varied dramatically among regions, upper and lower trim points were calculated at the regional level for each MS-DRG for the procedure. Cases with charges that were below the lower trim point or above the upper trim point were excluded from further analysis.

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

Trim points were determined as follows:

Q1	=	the first quartile (25th percentile total charge) of all patient records from the comparative database in a particular category
Q3	=	the third quartile (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)

Determining Actual Charges

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

Determining Expected Charges

The expected charge (ExpChg) for a hospitalization was equal to the average charge for all hospitalizations in that particular PA region/MS-DRG combination for the procedure analyzed. The hospital's expected charge was determined as the average (arithmetic mean) of the expected charges for the hospitalizations included in the hospital's charge analysis:

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

Determining Case-Mix Adjusted Charges

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

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

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

VOLUME RESULTS SECTION

Study Population

The study population for each procedure reported in the **Volume Results** section is designed to represent a clinically cohesive group of patients. See Appendix B for ICD-10-PCS, CPT-4, HCPCS Level II procedure definitions associated with each study population.

Inclusion Criteria

The study populations included records from Pennsylvania acute care hospitals, hospital outpatient departments, and ASCs for adults (18 years and older) during the defined report period with an ICD-10-PCS, CPT-4, HCPCS Level II procedure code in any procedure code position.

Displayed in the report component titled *Procedures Performed in the Inpatient Setting*

- The total number of cases performed in the inpatient acute care setting is reported for the following procedures:
    - Coronary Artery Bypass Graft
    - Left Atrial Appendage Closure
    - Mitral Valve Procedure
    - Surgical Aortic Valve Replacement
    - Transcatheter Aortic Valve Replacement
    - Tricuspid Valve Procedure

Displayed in the report component titled *Inpatient and Outpatient Volume,* by procedure group

- The total number of cases performed in the inpatient acute care setting, hospital outpatient department, and ambulatory surgery center is reported for the following procedures:
    - Cardiac Ablation
    - Cardioversion
    - Defibrillator Implantation
    - Pacemaker Implantation
    - Percutaneous Coronary Intervention

When two procedures from the same procedure group were performed during the same inpatient acute care hospitalization or outpatient encounter, the case was only counted once. If two procedures from different procedure groups (e.g., cardiac ablation and cardioversion) were performed during the same inpatient acute care hospitalization or outpatient encounter, the case was counted once in each procedure group.

Exclusion Criteria

The following types of records were excluded to determine the total number of cases in each procedure group. Note, the cases in these categories were also excluded from the outcome measures analyzed in the **Hospital Results** section.

1. Records with errors (e.g., systematic errors in coding of essential data fields such as dates, charges, etc.)
2. Duplicate records
3. Records with ending service date (i.e., Through Date) not in study period
4. Records representing an inpatient rehabilitation hospitalization (not acute care) defined by rehabilitation revenue codes 0024, 0118, 0128, 0138, 0148 or 0158

5. Non-adult records (< 18 years) or records with invalid age (e.g., records that did not have the necessary data for the calculation of age or for which age was > 124 years)

Overview of Measures Reported

Total Number of Cases

This represents inpatient cases and outpatient cases, where applicable, for adults who underwent the given procedure. Note that the number of inpatient cases reported in the **Volume Results** section of the report is often higher than the number of cases displayed in the **Hospital Results** section where only cases used to report outcome measures are included.

Inpatient Cases

This represents the total number of cases performed in a Pennsylvania inpatient acute care hospital.

Outpatient Cases

This represents the total number of cases performed in a Pennsylvania hospital outpatient department or ASC.

DATA TABLES

Table 1. Hospital Results – Statewide Utilization and Outcome Data, by Procedure

CABG

Number of Cases	13,757
Mortality	1.4%
7-Day Readmission	4.1%
30-Day Readmission	10.0%
90-Day Readmission	15.0%
Extended PLOS	3.6%
Average Hospital Charge	$261,971

PCI for a Heart Attack

Number of Cases	22,993
Mortality	1.8%
7-Day Readmission	4.2%
30-Day Readmission	9.0%
90-Day Readmission	14.9%
Extended PLOS	3.8%
Average Hospital Charge	$122,396

PCI without a Heart Attack

Number of Cases	9,796
Mortality	1.0%
7-Day Readmission	5.1%
30-Day Readmission	13.2%
90-Day Readmission	23.3%
Extended PLOS	4.4%
Average Hospital Charge	$134,702

SAVR

Number of Cases	3,746
Mortality	1.3%
7-Day Readmission	5.5%
30-Day Readmission	11.5%
90-Day Readmission	15.4%
Extended PLOS	3.5%
Average Hospital Charge	$340,523

SAVR with CABG

Number of Cases	1,907
Mortality	3.6%
7-Day Readmission	6.0%
30-Day Readmission	12.6%
90-Day Readmission	17.5%
Extended PLOS	3.7%
Average Hospital Charge	$376,602

TAVR

Number of Cases	11,106
7-Day Readmission	5.2%
30-Day Readmission	10.6%
90-Day Readmission	17.7%
Extended PLOS	5.6%
Average Hospital Charge	$240,236

Table 2. Hospital Results – Exclusions from Analyses[1], by Procedure and Measure

	CABG		PCI for a Heart Attack		PCI without a Heart Attack		SAVR		SAVR with CABG		TAVR	
	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases
Total Cases Before Exclusions	**17,246**	**100.0%**	**26,053**	**100.0%**	**13,121**	**100.0%**	**6,905**	**100.0%**	**2,037**	**100.0%**	**11,416**	**100.0%**
Universal Exclusions												
Records from hospitals with data problems	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Duplicate records	0	0.0%	2	<0.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Discharge date not in study period	1	<0.1%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Rehabilitation revenue code in record	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Invalid age, patients <18 or > 124 years	0	0.0%	0	0.0%	3	<0.1%	9	0.1%	0	0.0%	1	<0.1%
Total Universal Exclusions	**1**	**<0.1%**	**2**	**<0.1%**	**3**	**<0.1%**	**9**	**0.1%**	**0**	**0.0%**	**1**	**<0.1%**
Mortality Exclusions												
Universal exclusions	1	<0.1%	2	<0.1%	3	<0.1%	9	0.1%	0	0.0%	1	<0.1%
ICD-10-CM/PCS code-based exclusions	3,221	18.7%	290	1.1%	141	1.1%	3,038	44.0%	75	3.7%	194	1.7%
Not MS-DRG or MDC of interest	75	0.4%	2,288	8.8%	3,000	22.9%	58	0.8%	20	1.0%	76	0.7%
Missing or invalid discharge status	0	0.0%	0	0.0%	0	0.0%	1	<0.1%	0	0.0%	0	0.0%
Patients who left against medical advice	16	0.1%	180	0.7%	71	0.5%	6	0.1%	0	0.0%	8	0.1%
Patients transferred to another acute care hospital	176	1.0%	300	1.2%	110	0.8%	47	0.7%	35	1.7%	31	0.3%
Included in Mortality Measure[2]	**13,757**	**79.8%**	**22,993**	**88.3%**	**9,796**	**74.7%**	**3,746**	**54.3%**	**1,907**	**93.6%**	**11,106**	**97.3%**
7/30/90-Day Readmission Exclusions												
Universal exclusions	1	<0.1%	2	<0.1%	3	<0.1%	9	0.1%	0	0.0%	1	<0.1%
ICD-10-CM/PCS code-based exclusions	3,221	18.7%	290	1.1%	141	1.1%	3,038	44.0%	75	3.7%	194	1.7%
Not MS-DRG or MDC of interest	75	0.4%	2,288	8.8%	3,000	22.9%	58	0.8%	20	1.0%	76	0.7%
Missing or invalid discharge status	0	0.0%	0	0.0%	0	0.0%	1	<0.1%	0	0.0%	0	0.0%
Patients who left against medical advice	16	0.1%	180	0.7%	71	0.5%	6	0.1%	0	0.0%	8	0.1%
Patients transferred to another acute care hospital	176	1.0%	300	1.2%	110	0.8%	47	0.7%	35	1.7%	31	0.3%
In-hospital mortality	199	1.2%	409	1.6%	102	0.8%	49	0.7%	68	3.3%	59	0.5%
Missing or invalid length of stay	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%

Continued on next page

	CABG		PCI for a Heart Attack		PCI without a Heart Attack		SAVR		SAVR with CABG		TAVR	
	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases
7/30/90-Day Readmission Exclusions (continued)												
Length of stay outliers[3]	132	0.8%	198	0.8%	87	0.7%	36	0.5%	17	0.8%	98	0.9%
Out-of-state residents	1,309	7.6%	1,262	4.8%	594	4.5%	470	6.8%	181	8.9%	1,007	8.8%
Discharge to hospice	7	<0.1%	49	0.2%	25	0.2%	5	0.1%	5	0.2%	5	<0.1%
Multiple missing or invalid patient identifiers	21	0.1%	102	0.4%	15	0.1%	10	0.1%	1	<0.1%	6	0.1%
Included in 7/30/90-Day Readmission Measure	**12,089**	**70.1%**	**20,973**	**80.5%**	**8,973**	**68.4%**	**3,176**	**46.0%**	**1,635**	**80.3%**	**9,931**	**87.0%**
Extended Postoperative Length of Stay Exclusions												
Universal exclusions	1	<0.1%	2	<0.1%	3	<0.1%	9	0.1%	0	0.0%	1	<0.1%
ICD-10-CM/PCS code-based exclusions	3,221	18.7%	290	1.1%	141	1.1%	3,038	44.0%	75	3.7%	194	1.7%
Not MS-DRG or MDC of interest	75	0.4%	2,288	8.8%	3,000	22.9%	58	0.8%	20	1.0%	76	0.7%
Missing or invalid discharge status	0	0.0%	0	0.0%	0	0.0%	1	<0.1%	0	0.0%	0	0.0%
Patients who left against medical advice	16	0.1%	180	0.7%	71	0.5%	6	0.1%	0	0.0%	8	0.1%
Patients transferred to another acute care hospital	176	1.0%	300	1.2%	110	0.8%	47	0.7%	35	1.7%	31	0.3%
In-hospital mortality	199	1.2%	409	1.6%	102	0.8%	49	0.7%	68	3.3%	59	0.5%
Discharge to hospice	13	0.1%	65	0.2%	35	0.3%	7	0.1%	6	0.3%	8	0.1%
Postoperative length of stay inconsistencies[4]	13	0.1%	358	1.4%	391	3.0%	8	0.1%	2	0.1%	4	<0.1%
Included in Extended PLOS Measure	**13,532**	**78.5%**	**22,161**	**85.1%**	**9,268**	**70.6%**	**3,682**	**53.3%**	**1,831**	**89.9%**	**11,035**	**96.7%**
Charges Exclusions												
Universal exclusions	1	<0.1%	2	<0.1%	3	<0.1%	9	0.1%	0	0.0%	1	<0.1%
ICD-10-CM/PCS code-based exclusions	3,221	18.7%	290	1.1%	141	1.1%	3,038	44.0%	75	3.7%	194	1.7%
Not MS-DRG or MDC of interest	75	0.4%	2,288	8.8%	3,000	22.9%	58	0.8%	20	1.0%	76	0.7%
Missing or invalid discharge status	0	0.0%	0	0.0%	0	0.0%	1	<0.1%	0	0.0%	0	0.0%
Patients who left against medical advice	16	0.1%	180	0.7%	71	0.5%	6	0.1%	0	0.0%	8	0.1%
Patients transferred to another acute care hospital	176	1.0%	300	1.2%	110	0.8%	47	0.7%	35	1.7%	31	0.3%
Invalid charges	16	0.1%	27	0.1%	31	0.2%	2	<0.1%	1	<0.1%	5	<0.1%
ECMO/Tracheostomy MS-DRG 003 with a principal diagnosis from MDC 5[5]	99	0.6%	0	0.0%	0	0.0%	30	0.4%	54	2.7%	16	0.1%

Continued on next page

	CABG		PCI for a Heart Attack		PCI without a Heart Attack		SAVR		SAVR with CABG		TAVR	
	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases
Charge Exclusions (continued)												
Charge outliers	206	1.2%	144	0.6%	106	0.8%	65	0.9%	25	1.2%	312	2.7%
No reference data	173	1.0%	199	0.8%	220	1.7%	145	2.1%	268	13.2%	3	<0.1%
Included in Average Charges Calculation	**13,263**	**76.9%**	**22,623**	**86.8%**	**9,439**	**71.9%**	**3,504**	**50.7%**	**1,559**	**76.5%**	**10,770**	**94.3%**
Medicare Payment Exclusions												
Universal exclusions	1	<0.1%	2	<0.1%	3	<0.1%	9	0.1%	0	0.0%	1	<0.1%
ICD-10-CM/PCS code-based exclusions	3,221	18.7%	290	1.1%	141	1.1%	3,038	44.0%	75	3.7%	194	1.7%
Not MS-DRG or MDC of interest	75	0.4%	2,288	8.8%	3,000	22.9%	58	0.8%	20	1.0%	76	0.7%
Missing or invalid discharge status	0	0.0%	0	0.0%	0	0.0%	1	<0.1%	0	0.0%	0	0.0%
Patients who left against medical advice	16	0.1%	180	0.7%	71	0.5%	6	0.1%	0	0.0%	8	0.1%
Patients transferred to another acute care hospital	176	1.0%	300	1.2%	110	0.8%	47	0.7%	35	1.7%	31	0.3%
Out-of-state residents	1,339	7.8%	1,299	5.0%	610	4.6%	483	7.0%	194	9.5%	1,026	9.0%
Not a CMS beneficiary	4,288	24.9%	9,051	34.7%	2,532	19.3%	1,525	22.1%	397	19.5%	552	4.8%
Not Medicare entitled at time of discharge	101	0.6%	141	0.5%	50	0.4%	NR	NR	11	0.5%	15	0.1%
Not enrolled in Medicare FFS during month of discharge	4,204	24.4%	6,971	26.8%	3,611	27.5%	855	12.4%	679	33.3%	5,120	44.8%
No matching CMS FFS payment	580	3.4%	816	3.1%	491	3.7%	116	1.7%	85	4.2%	283	2.5%
CMS not the primary payer	179	1.0%	296	1.1%	112	0.9%	43	0.6%	25	1.2%	70	0.6%
CMS FFS Payment <$1,600 (2023) or <$1,632 (2024)[6]	22	0.1%	76	0.3%	145	1.1%	NR	NR	NR	NR	16	0.1%
Included in Average Medicare Payment Calculation	**3,044**	**17.7%**	**4,343**	**16.7%**	**2,245**	**17.1%**	**689**	**10.0%**	**515**	**25.3%**	**4,024**	**35.2%**

[1] The exclusions are listed in the order in which they were removed from the reference database.

[2] Mortality ratings are not reported for the TAVR procedure group.

[3] Records with a length of stay (LOS) greater than the trim point (>99th percentile) for a procedure and the year of hospital discharge were excluded.

[4] Records with the date of the first procedure of interest missing or occurs before admit date or after discharge date were excluded.

[5] Records assigned to MS-DRG 003 (ECMO or Tracheostomy with Mechanical Ventilation >96 Hours or Principal Diagnosis Except Face, Mouth, and Neck with Major O.R. Procedures) with a principal diagnosis from MDC 5 (Diseases and Disorders of the Circulatory System) were excluded.

[6] The Medicare Part A inpatient hospital deductible beneficiaries paid when admitted to the hospital in 2023 and 2024, https://www.cms.gov/newsroom/fact-sheets/2024-medicare-parts-b-premiums-and-deductibles

Table 3. Volume Results – Exclusions from Analyses, by Procedure

Table 3A. Exclusions[1] for Coronary Artery Bypass Graft, Left Atrial Appendage Closure, Mitral Valve Procedure

	Coronary Artery Bypass Graft		Left Atrial Appendage Closure		Mitral Valve Procedure	
	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases
Total Cases Before Exclusions	**17,246**	**100.0%**	**10,636**	**100.0%**	**5,435**	**100.0%**
Records from facilities with data problems	0	0.0%	0	0.0%	0	0.0%
Duplicate records	0	0.0%	0	0.0%	0	0.0%
Ending service date not in study period	1	<0.1%	0	0.0%	0	0.0%
Rehabilitation revenue code in record	0	0.0%	0	0.0%	0	0.0%
Invalid age, patients < 18 or > 124 years	0	0.0%	1	<0.1%	5	0.1%
Included in Inpatient Volume	**17,245**	**100.0%**	**10,635**	**100.0%**	**5,430**	**99.9%**

[1] The exclusions are listed in the order in which they were removed from the reference database.

Table 3B. Exclusions[1] for Surgical Aortic Valve Replacement, Transcatheter Aortic Valve Replacement, Tricuspid Valve Procedure

	Surgical Aortic Valve Replacement		Transcatheter Aortic Valve Replacement		Tricuspid Valve Procedure	
	# Cases	% Cases	# Cases	% Cases	# Cases	% Cases
Total Cases Before Exclusions	**6,905**	**100.0%**	**11,416**	**100.0%**	**1,043**	**100.0%**
Records from facilities with data problems	0	0.0%	0	0.0%	0	0.0%
Duplicate records	0	0.0%	0	0.0%	0	0.0%
Ending service date not in study period	0	0.0%	0	0.0%	0	0.0%
Rehabilitation revenue code in record	0	0.0%	0	0.0%	0	0.0%
Invalid age, patients < 18 or > 124 years	9	0.1%	1	<0.1%	5	0.5%
Included in Inpatient Volume	**6,896**	**99.9%**	**11,415**	**100.0%**	**1,038**	**99.5%**

[1] The exclusions are listed in the order in which they were removed.

Table 3C. Exclusions[1] for Cardiac Ablation

	Inpatient		Outpatient	
	# Cases	% Cases	# Cases	% Cases
Total Cases Before Exclusions	**7,705**	**100.0%**	**22,477**	**100.0%**
Records from facilities with data problems	0	0.0%	0	0.0%
Duplicate records	0	0.0%	1	<0.1%
Ending service date not in study period	0	0.0%	1	<0.1%
Rehabilitation revenue code in record	1	<0.1%	NA	NA
Invalid age, patients < 18 or > 124 years	2	<0.1%	42	0.2%
Included in Inpatient and Outpatient Volume	**7,702**	**100.0%**	**22,433**	**99.8%**

[1] The exclusions are listed in the order in which they were removed.
NA Not applicable. There are no inpatient rehabilitation revenue codes in outpatient records.

Table 3D. Exclusions[1] for Cardioversion

	Inpatient		Outpatient	
	# Cases	% Cases	# Cases	% Cases
Total Cases Before Exclusions	**24,200**	**100.0%**	**32,351**	**100.0%**
Records from facilities with data problems	0	0.0%	0	0.0%
Duplicate records	2	<0.1%	5	<0.1%
Ending service date not in study period	0	0.0%	0	0.0%
Rehabilitation revenue code in record	10	0.0%	NA	NA
Invalid age, patients < 18 or > 124 years	28	0.1%	8	<0.1%
Included in Inpatient and Outpatient Volume	**24,160**	**99.8%**	**32,338**	**100.0%**

[1] The exclusions are listed in the order in which they were removed.
NA Not applicable. There are no inpatient rehabilitation revenue codes in outpatient records.

Table 3E. Exclusions[1] for Defibrillator Implantation

	Inpatient		Outpatient	
	# Cases	% Cases	# Cases	% Cases
Total Cases Before Exclusions	**4,349**	**100.0%**	**7,136**	**100.0%**
Records from facilities with data problems	0	0.0%	0	0.0%
Duplicate records	0	0.0%	1	<0.1%
Ending service date not in study period	0	0.0%	3	<0.1%
Rehabilitation revenue code in record	0	0.0%	NA	NA
Invalid age, patients < 18 or > 124 years	1	<0.1%	3	<0.1%
Included in Inpatient and Outpatient Volume	**4,348**	**100.0%**	**7,129**	**99.9%**

[1] The exclusions are listed in the order in which they were removed.
NA Not applicable. There are no inpatient rehabilitation revenue codes in outpatient records.

Table 3F. Exclusions[1] for Pacemaker Implantation

	Inpatient		Outpatient	
	# Cases	% Cases	# Cases	% Cases
Total Cases Before Exclusions	**15,290**	**100.0%**	**9,716**	**100.0%**
Records from facilities with data problems	0	0.0%	0	0.0%
Duplicate records	0	0.0%	2	<0.1%
Ending service date not in study period	0	0.0%	4	<0.1%
Rehabilitation revenue code in record	0	0.0%	NA	NA
Invalid age, patients < 18 or > 124 years	2	<0.1%	2	<0.1%
Included in Inpatient and Outpatient Volume	**15,288**	**100.0%**	**9,708**	**99.9%**

[1] The exclusions are listed in the order in which they were removed.
NA Not applicable. There are no inpatient rehabilitation revenue codes in outpatient records.

Table 3G. Exclusions[1] for Percutaneous Coronary Intervention

	Inpatient		Outpatient	
	# Cases	% Cases	# Cases	% Cases
Total Cases Before Exclusions	**39,174**	**100.0%**	**21,893**	**100.0%**
Records from facilities with data problems	0	0.0%	0	0.0%
Duplicate records	2	<0.1%	2	<0.1%
Ending service date not in study period	0	0.0%	2	<0.1%
Rehabilitation revenue code in record	0	0.0%	NA	NA
Invalid age, patients < 18 or > 124 years	3	<0.1%	0	0.0%
Included in Inpatient and Outpatient Volume	**39,169**	**100.0%**	**21,889**	**100.0%**

[1] The exclusions are listed in the order in which they were removed.
NA Not applicable. There are no inpatient rehabilitation revenue codes in outpatient records.

APPENDICES

Appendix A. Definitions – Hospital Results

For each procedure included in the **Hospital Results** section of the report, the ICD-10-CM/PCS codes and MDC/MS-DRGs used to define study populations and code-based exclusions can be downloaded using the links below.

Coronary Artery Bypass Graft

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinHospResult_CABG_2023-2024.xlsx

Percutaneous Coronary Intervention for a Heart Attack

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinHospResult_PCI_AMI_2023-2024.xlsx

Percutaneous Coronary Intervention without a Heart Attack

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinHospResult_PCI_NoAMI_2023-2024.xlsx

Surgical Aortic Valve Replacement

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinHospResult_SAVR_2023-2024.xlsx

Surgical Aortic Valve Replacement with Coronary Artery Bypass Graft

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinHospResult_SAVR_CABG_2023-2024.xlsx

Transcatheter Aortic Valve Replacement

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinHospResult_TAVR_2023-2024.xlsx

Appendix B. Definitions – Volume Results

For each procedure included in the **Volume Results** section of the report, the ICD-10-PCS, CPT-4 and HCPCS Level II procedure codes can be downloaded using the links below.

Cardiac Ablation

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_CardiacAblation_2023-2024.xlsx

Cardioversion

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_Cardioversion_2023-2024.xlsx

Coronary Artery Bypass Graft

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_CABG_2023-2024.xlsx

Defibrillator Implantation

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_DefibrillatorImplant_2023-2024.xlsx

Left Atrial Appendage Closure

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_LeftAtrialAppendClos_2023-2024.xlsx

Mitral Valve Procedure

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_MitralValveProc_2023-2024.xlsx

Pacemaker Implantation

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_PacemakerImplant_2023-2024.xlsx

Percutaneous Coronary Intervention

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_PCI_2023-2024.xlsx

Surgical Aortic Valve Replacement

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_SAVR_2023-2024.xlsx

Transcatheter Aortic Valve Replacement

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_TAVR_2023-2024.xlsx

Tricuspid Valve Procedure

https://www.phc4.org/wp-content/uploads/CardiacProceduresReport_DefinVol_TricuspidValveProc_2023-2024.xlsx

Appendix C. Valid Discharge Status Codes

Code	Description
01	Discharged to home or self-care (routine discharge)
02	Discharged/transferred to a short-term general hospital for inpatient care
03	Discharged/transferred to skilled nursing facility (SNF) with Medicare certification in anticipation of skilled care
04	Discharged/transferred to a facility that provides custodial or supportive care
05	Discharged/transferred to a designated cancer center or children's hospital
06	Discharged/transferred to home under care of an organized home health service organization in anticipation of covered skilled care
07	Left against medical advice or discontinued care
20	Expired
21	Discharged/transferred to court/law enforcement
43	Discharged/transferred to a federal health care facility
50	Discharged to hospice – home
51	Discharged to hospice – medical facility (certified) providing hospice level of care
61	Discharged/transferred to a hospital-based Medicare approved swing bed
62	Discharged/transferred to an inpatient rehabilitation facility (IRF) including rehabilitation distinct part units of a hospital
63	Discharged/transferred to a Medicare certified long term care hospital (LTCH)
64	Discharged/transferred to a nursing facility certified under Medicaid but not certified under Medicare
65	Discharged/transferred to a psychiatric hospital or psychiatric distinct part unit of a hospital
66	Discharged/transferred to a critical access hospital (CAH)
69	Discharged/transferred to a designated disaster alternative care site
70	Discharged/transferred to another type of health care institution not defined elsewhere in this code list
81	Discharged to home or self care (routine discharge) with a planned acute care hospital inpatient readmission
82	Discharged/transferred to a short term general hospital for inpatient care with a planned acute care hospital inpatient readmission
83	Discharged/transferred to a skilled nursing facility (SNF) with Medicare certification with a planned acute care hospital inpatient readmission
84	Discharged/transferred to a facility that provides custodial or supportive care with a planned acute care hospital inpatient readmission
85	Discharged/transferred to a designated cancer center or children's hospital with a planned acute care hospital inpatient readmission
86	Discharged/transferred to home under care of organized home health service organization in anticipation of covered skilled care with a planned acute care hospital inpatient readmission
87	Discharged/transferred to court/law enforcement with a planned acute care hospital inpatient readmission
88	Discharged/transferred to a federal health care facility with a planned acute care hospital inpatient readmission
89	Discharged/transferred to a hospital-based Medicare approved swing bed with a planned acute care hospital inpatient readmission
90	Discharged/transferred to an inpatient rehabilitation facility (IRF) including rehabilitation distinct part units of a hospital with a planned acute care hospital inpatient readmission
91	Discharged/transferred to a Medicare certified long term care hospital (LTCH) with a planned acute care hospital inpatient readmission
92	Discharged/transferred to a nursing facility certified under Medicaid but not certified under Medicare with a planned acute care hospital inpatient readmission
93	Discharged/transferred to a psychiatric hospital or psychiatric distinct part unit of a hospital with a planned acute care hospital inpatient readmission
94	Discharged/transferred to a critical access hospital (CAH) with a planned acute care hospital inpatient readmission
95	Discharged/transferred to another type of health care institution not defined elsewhere in this code list with a planned acute care hospital inpatient readmission

Appendix D. Example of Logistic Regression

Calculations Used in Determining Expected Mortality Rates for a Given Hospital Coronary Artery Bypass Graft

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

Actual Percent Mortality: Total number of deaths (death is a discharge status equal to 20) / total number of hospitalizations.

Expected Percent Mortality: Mean of the predicted probabilities of death for each hospitalization (PDeath).

Step 1: Calculate the predicted probability of death for each hospitalization (PDeath):

$$\beta X = (\beta_0 + \text{TimeFactor}) + \beta_1 X_1 + \ldots\ldots + \beta_9 X_9 + \ldots + \beta_{15} X_{15}$$
$$= (-10.0454) + (0.9550)(X_1) + \ldots + (0.8893)(X_9) + \ldots + (0.7045)(X_{15})$$

Where:

X_1 = Female (1 if true, 0 if false)

…

X_9 = Heart Failure – Biventricular and End Stage or Left, Reduced Ejection Fraction (HFrEF) (1 if true, 0 if false)

…

X_{15} = Intra-aortic Ballon Pump (IABP) Prior to First Cardiac Procedure of Interest (1 if true, 0 if false)

β's are the regression coefficients that correspond to each risk factor (X).

A time factor (TimeFactor) is added to the intercept so the statewide expected rate for the current study period is equal to the actual statewide rate for this same period.

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

where $e \approx 2.7182818285$

Step 2: Calculate the mean PDeath for a hospital (expected percent of deaths):

$$\text{Mean PDeath} = \frac{\sum \text{PDeath}}{n}$$

Appendix E. Example of Linear Regression

Calculations Used in Determining Extended Postoperative Length of Stay (EPLOS) Rates for a Given Hospital Transcatheter Aortic Valve Replacement

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

Actual Percent EPLOS: Total number of hospitalizations with EPLOS / total number of hospitalizations.

Step 1: Calculate the predicted log transformed postoperative length of stay for each hospitalization (PPLOS):

$$\beta X = (\beta_0 + \text{TimeFactor}) + \beta_1 X_1 + \ldots \beta_{31} X_{31} + \ldots \beta_{45} X_{45}$$
$$= (1.5134) + (0.0438)(X_1) + \ldots (0.0722)(X_{31}) + \ldots (0.0279)(X_{45})$$

Where:

X_1 = Female (1 if true, 0 if false)

…

X_{31} = Vascular Disease (1 if true, 0 if false)

…

X_{45} = Atrial Fibrillation and Flutter on Admission (1 if true, 0 if false)

β's are the regression coefficients that correspond to each risk factor (X).

A time factor (TimeFactor) is added to the intercept so the statewide expected average log PLOS for the current study period is equal to the actual statewide average log PLOS for this same period.

Step 2: Calculate the residual log transformed postoperative length of stay (*Residual*) as actual log transformed postoperative length of stay (*APLOS*) minus *PPLOS* for each hospitalization.

$$Residual = (APLOS - PPLOS)$$

Step 3: Calculate statewide statistics.

Step 3a: Calculate the average *Residual* using statewide records.

$$\text{Average } Residual \left(\overline{Residual}\right) = \frac{\sum_{i=1}^{n}(Residual_i)}{n}$$

Step 3b: Calculate the standard deviation of *Residual* using statewide records.

$$\text{Standard Deviation of } Residual \ (SDResidual) = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(Residual_i - \overline{Residual}\right)^2}$$

Step 4: An *EPLOS* is counted when the *Residual* exceeds two standard deviations above the average *Residual*.

$$EPLOS \text{ if } Residual > \left(\overline{Residual} + 2 * SDResidual\right)$$

Expected Percent EPLOS Total number of hospitalizations with EPLOS statewide / total number of hospitalizations statewide. The expected percent EPLOS for each hospital is the same as the statewide rate of EPLOS.

Appendix F. Example of Case-Mix Adjustment

Calculations Used in Determining Average Charge for a Hospital
Example Hospital: Hospital "A" in Southwestern PA, Region 1
Percutaneous Coronary Intervention (PCI) for a Heart Attack

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

Actual Average Charge, Hospital: Mean of the charges among all hospitalizations for Hospital A (Average ActChg).

Actual Average Charge, Region: Mean of the charges among all hospitalizations for the hospital region (Region 1).

Expected Average Charge, Hospital: Mean of the expected charges among all hospitalizations for Hospital A (Average ExpChg).

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

ExpChg is based on the MS-DRG of the hospitalization and is equal to the average charge for all hospitalizations (after exclusion) in the hospital's same region and MS-DRG group.

Region 1 – Southwestern PA:

MS-DRG 246: $143,845
MS-DRG 247: $95,439
MS-DRG 250: $83,998
MS-DRG 251: $70,783
MS-DRG 321: $144,923
MS-DRG 322: $100,485
MS-DRG 323: $193,907
MS-DRG 324: $148,151

Step 2: Calculate the average expected charge for Hospital A (ExpChg):

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

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

Nine Pennsylvania Regions:

1. Southwestern – Allegheny, Armstrong, Beaver, Butler, Fayette, Greene, Washington, and Westmoreland counties
2. Northwestern – Cameron, Clarion, Clearfield, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, McKean, Mercer, Potter, Venango, and Warren counties
3. Southern Allegheny – Bedford, Blair, Cambria, Indiana, and Somerset counties
4. Northcentral – Centre, Clinton, Columbia, Lycoming, Mifflin, Montour, Northumberland, Snyder, Tioga, and Union counties
5. Southcentral – Adams, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster, Lebanon, Perry, and York counties
6. Northeastern – Bradford, Lackawanna, Luzerne, Monroe, Pike, Sullivan, Susquehanna, Wayne, and Wyoming counties
7. Eastcentral – Berks, Carbon, Lehigh, Northampton, and Schuylkill counties
8. Southeastern – Bucks, Chester, Delaware, and Montgomery counties
9. Philadelphia – Philadelphia County