TECHNICAL NOTES
for Knee and Hip Replacements

April
2015

Pennsylvania Health Care Cost Containment Council
Report Period: Calendar Year 2013
January 1, 2013 through December 31, 2013 Discharges

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OVERVIEW

The Technical Notes serve as a technical supplement to the Pennsylvania Health Care Cost Containment Council (PHC4) report on knee and hip replacement surgery for discharges from January 1, 2013 through December 31, 2013. This document describes the methodology and development of the report and includes information on statewide results, cases excluded from the analysis, and risk-adjustment models.

- The analysis included adult patients age 18 or older who underwent a total knee or hip replacement procedure in a Pennsylvania general acute care (GAC) hospital. Results are reported separately for knee and hip replacements.

- The following measures are reported:

  - Total number of knee and hip replacement cases for hospitals and surgeons, including elective and non-elective[1] cases.

  - Risk-adjusted 30-day readmissions considered to be "unplanned" based on the Centers for Medicare and Medicaid Services planned readmission algorithm designed specifically for total knee and hip replacements likely to be considered elective.[2] This measure is reported for hospitals with five or more cases in the analysis.

  - Average hospital charge (case-mix adjusted) is reported for hospitals with at least 11 cases.

  - Calendar year 2012 average Medicare payment is reported for hospitals with at least 11 cases.

  - Calendar year 2012 average hospital charge (case-mix adjusted) is reported for the cases in the 2012 average Medicare payment measure. Average charge is reported for hospitals with 11 or more cases.

The rigorous methodology described in this document was developed to account for the differences among individual patients that had the potential to influence the outcome of knee or hip replacement.

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

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1 Non-elective cases are clinically complex as defined by the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes in Appendix A, Table A1 and cases *not* in the study's Medicare Severity-Adjusted Diagnosis-Related Groups (MS-DRG) (see Appendix A, Table A2 for MS-DRGs *not* excluded from the study). The clinically complex cases were excluded from the readmission, average charge, and average Medicare payment analyses.

2 Centers for Medicare and Medicaid Services. "2014 Procedure Specific Readmission Measures Updates and Specifications Report: Elective Primary Total Hip Arthroplasty (THA) and/or Total Knee Arthroplasty (TKA) – Version 3.0." March 2014. Available at http://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/Measure-Methodology.html.

DATA COLLECTION AND VERIFICATION

The data for the report on knee and hip replacements, obtained from the inpatient UB-04 (Uniform Billing) form, was submitted electronically to PHC4 by Pennsylvania GAC hospitals that performed knee and hip replacements primarily on adults. Federal hospitals were not included. The data included demographic information, hospital charges, and International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure codes.

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

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 submissions were matched to inpatient records. Error reports for UB-04 data were then generated and returned to each facility with an opportunity to correct any problems. Similarly, laboratory test results were evaluated each quarter and summary reports indicating data anomalies were sent to each facility, again with an opportunity to make corrections.

Hospitals were given an opportunity to confirm the operating physician volume data. Hospitals were also given an opportunity to verify the average Medicare payment reported for their facilities prior to the public release of the information.

STUDY POPULATION

Inclusion Criteria

The study population included records for adult (18 years of age and older) inpatients discharged from Pennsylvania GAC hospitals between January 1, 2013 and December 31, 2013 who underwent total knee and hip replacements, as identified by the presence of one of the following ICD-9-CM procedure codes in either the principal or secondary procedure code positions of the discharge record.

- 81.54   Total Knee Replacement
- 81.51   Total Hip Replacement

Analyses were performed separately for knee and hip replacements.

Exclusion Criteria

Cases meeting certain criteria were excluded from the outcome analyses. Non-elective (i.e., clinically complex cases*) were excluded from:
- 30-day readmissions
- average hospital charge

Additional exclusions for 30-day readmissions included:
- Cases with invalid or missing discharge status.
- Patients who left against medical advice.
- Patients who were transferred to an acute care facility.
- Patients who died during the hospitalization in which the surgery was performed.
- Additional cases within 30 days that met the study population criteria.
- Cases with invalid data (i.e., social security number, date of birth, or sex), which could not be linked to subsequent hospitalizations.
- Out-of-state residents, because these patients could undergo a knee or hip replacement in a Pennsylvania hospital, return to their state of residence, and be readmitted to a hospital in their home state. As such, readmission data would not be available for these patients.

Additional exclusions for average hospital charge included:
- Cases in tracheostomy Diagnostic Related Group (MS-DRG) 003.
- Cases in low volume MS-DRGs, including MS-DRG groups when a particular combination of PA region and MS-DRG group had fewer than 10 cases.
- Charge outliers, which were determined using the "+/- 3.0 interquartile range" method (after accounting for differences in charges between PA region and MS-DRG group).

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

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* Clinically complex cases as defined by the ICD-9-CM codes in Appendix A, Table A1 and cases *not* in the study MS-DRGs (see Appendix A, Table A2 for MS-DRGs *not* excluded from the study).

MEASURES REPORTED

Number of Cases

The number of total knee or hip replacement surgery cases is reported for hospitals and surgeons. The total number of cases includes elective and non-elective[1] procedures. Not included in this measure are procedures performed on patients less than 18 years old, those performed in Veterans' hospitals, or those performed in other states by surgeons who also practice outside Pennsylvania, so the actual number of cases for hospitals or surgeons might be higher.

If two joint replacements were performed during the same hospitalization, the case was only counted once. Note that if two joint replacements were performed during the same hospitalization and two different surgeons performed the surgeries, an exception was made when counting surgeon volume. Each replacement was counted once for each surgeon. If a knee and a hip replacement were performed during the same hospitalization, the case was assigned to either the knee or hip study population based on the particular diagnosis and procedure codes present in the patient record.

Risk-Adjusted 30-Day Readmissions Rating

A hospital readmission was defined as a rehospitalization to a Pennsylvania GAC hospital within 30 days of discharge from the hospitalization in which the knee or hip replacement was performed. A readmission was counted only if it was considered "unplanned,"; that is, the patient was readmitted for a reason that was not defined as planned using the Centers for Medicare and Medicaid Services planned readmission algorithm developed specifically for total knee and hip replacements that are likely to be elective.[2]

A hospitalization that resulted in more than one readmission within 30 days was counted only once even though it resulted in multiple readmissions. If, over the study period, a patient had multiple discharges for knee or hip surgery, each discharge was independently investigated to determine whether it had a readmission within 30 days of that discharge with one exception. If a second hospitalization for knee or hip replacement occurred within 30 days of the first or index hospitalization, the second hospitalization was excluded from the readmission analysis.

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

Case-Mix Adjusted Average Hospital Charge

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

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[1] Non-elective cases are clinically complex as defined by the ICD-9-CM codes in Appendix A, Table A1 and cases *not* in the study MS-DRGs (see Appendix A, Table A2 for MS-DRGs *not* excluded from the study).

[2] Centers for Medicare and Medicaid Services. "2014 Procedure Specific Readmission Measures Updates and Specifications Report: Elective Primary Total Hip Arthroplasty (THA) and/or Total Knee Arthroplasty (TKA) – Version 3.0." March 2014. Available at http://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/Measure-Methodology.html.

Calendar Year 2012 Average Medicare Fee-for-Service Payment

The average Medicare payment is for Medicare fee-for-service (FFS) cases only (adult PA residents) and is for calendar year 2012, since this was the most recent Medicare payment data available.

The Medicare payment data for 2012 was provided to PHC4 by the Centers for Medicare and Medicaid Services (CMS) and then matched by PHC4 to the 2012 knee and hip cases meeting the study population criteria (after the clinically complex cases were removed). The average Medicare payment was trimmed for outliers as appropriate. The average payment was calculated using the dollar amount that CMS provided for the Medicare Part A hospital insurance fund payment. Patient liabilities (e.g., coinsurance and deductible dollar amounts) were not included. Also not included were payments from Medicare Advantage plans (Medicare HMOs) and any special pass-through payments facilities sometimes receive for unusual capital or other costs.

The average payment was calculated by summing the Medicare FFS payment amounts for the cases and dividing the sum by the number of cases.

To meet current CMS privacy guidelines, average payments (and the number of cases included in the average payment) are only displayed for hospitals with 11 or more cases in the average payment analysis.

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

Calendar Year 2012 Average Hospital Charge for Medicare Fee-for-Service Cases

Case-mix adjusted average charge is reported for the Medicare cases included in the 2012 average Medicare payment. While the same cases included in the average Medicare payment were included in the charge analysis, the final case-mix adjusted average charge may include fewer cases as a result of exclusions specific to the charge analysis. Average charges are not reported when payment information is not reported or when there are fewer than 11 cases in the average charge analysis.

RISK-ADJUSTMENT METHODOLOGY

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

Model Development

For modeling 30-day readmissions, the reference database included knee and hip discharges from January 1, 2013 through December 31, 2013 (after exclusions). Data Table 1 displays frequencies for the datasets and statewide outcomes. Knee and hip replacements were modeled separately.

Identifying potential risk factors. The first step in building the models was to identify potential risk factors, that is, factors that potentially contributed to readmission within 30 days of discharge. 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 patient characteristics, socioeconomic factors, laboratory test results, and diagnoses and procedures identified by ICD-9-CM codes. Definitions for ICD-9-CM code-based variables are available in Appendix B.

Using the reference database, potential risk factors were subject to univariate analysis to determine which, because of their potential to predict the event of interest, should be tested for inclusion in the model. Variables were constructed and analyzed as linear (continuous), categorical, and binary as appropriate. For some factors multiple forms of variable construction were analyzed to determine which approach best fit the data (i.e., provided the highest model likelihood). For example, patient age was tested as a linear, linear spline with up to two knots, or quadratic factor. The linear spline approach yielded the best results for both models.

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

Categorical and binary variables were selected for testing in the model based on the following criteria:
- Minimum volume: For categorical variables, each category represented at least one percent of the total volume. For binary variables, cases with the risk factor were required to represent at least one percent of the total volume. Exceptions were made to this criterion when a variable had particular clinical relevance to the outcome.

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- Order of risk: For categorical variables, categories farther away from the "typical" category were required to have rates of increasing risk (e.g., when the typical category was defined as level A, categories B, C, D, and E were required to have increasingly higher rates of risk). For binary variables, cases with the risk factor were required to have a higher rate of risk than cases without the risk factor.
- Significance: Variables were required to have significance ($p<0.10$).

Model selection. Using binary logistic regression, risk factors selected for testing were added to the model in the following order: 1) patient characteristics and socioeconomic factors, (gender, race/ethnicity, age, poverty rate, education, percent not speaking English very well), 2) laboratory test results, then 3) ICD-9-CM code-based variables. All factors within a risk factor type were evaluated before considering factors from the next type.

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

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. In rare instances, exceptions were made to the Schwarz criterion for factors identified in the research literature as clinically important.

Bootstrap validation. Once the model variables were chosen, the model was validated using the bootstrap technique to evaluate the stability of each factor in the prepared model. Using this technique, one hundred sample datasets were randomly generated from the reference database. Records were allowed to appear multiple times in the sample datasets if they were selected repeatedly. The prepared model was then fit to each sample dataset to determine the percent of sample models in which each factor maintained significance ($p<0.10$). Risk factors at or above a 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 (reflective of an increased risk) in at least 75% of the sample models. (See the "Coefficients and Odds Ratios" section for a description of model coefficients.)

Measure of Model Adequacy

The c-statistic was used to measure model adequacy. The c-statistic, the measure of "goodness of fit" used to describe a logistic regression model, is a common measure for models with binary dependent variables. For binary outcomes, the c-statistic is defined as the area under the receiver operating characteristic (ROC) curve.* The c-statistic ranges between 0.5 and 1.0, with higher values associated with better discrimination, and can be expressed as a percent ranging from 50% to 100%. In some respects, the c-statistic is similar to the R^2 (Coefficient of Determination) commonly used in linear regression. Both the c-statistic and R^2 approach 1.0 for models that perfectly discriminate. However, unlike R^2, the c-statistic is not dependent on the frequency of the outcome. The c-statistics for the 30-day readmissions models are listed in Data Tables 3 and 4.

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

Coefficients and Odds Ratios

Coefficients are mathematical values derived from the regression analysis that correspond to a given level of risk. They are used in the mathematical formula that calculates a patient's overall predicted risk of the event (readmission). The odds ratios are used to interpret the impact of the risk factors on the probability of the event. For a binary variable, the odds ratio is the change in the odds for a patient with the risk factor compared to a patient without it. For example, in the knee readmission model, the odds ratio for Long-term (current) Use of Steroids indicates that patients with this factor were more than two times as likely to be readmitted within 30 days than patients without this factor. The coefficients and odds ratios for each risk factor included in the readmission models are listed in Data Tables 3 and 4.

CALCULATING HOSPITAL-SPECIFIC OUTCOMES

Separate analyses were performed to determine, for each hospital, the actual percent of 30-day readmissions. 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. Ratings were reported for hospitals with five or more cases.

Determining Actual Values

The 30-day readmission percent was determined by dividing the number of hospitalizations for which the patient was readmitted at least once to any Pennsylvania GAC hospital within 30 days of discharge, by the total number of hospitalizations included in the readmissions analysis.

Determining Expected Values

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

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

where:

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

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

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

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

where $e \approx 2.7182818285$

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

Determining Statistical Ratings

Significance tests (using the binomial distribution, see below) were performed for the readmissions measures. 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 (e.g., readmission) for each observation studied was equal to the probability provided by the risk models.

- 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 readmissions 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., readmissions) that were observed (i.e., a = 1 readmission, a = 2 readmissions, etc.) in N hospitalizations. The value of "a" ranged from 0 through N (in other words, $0 \leq a \leq N$)

    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 readmission) for a particular hospital.

The rating process evaluated both fewer than expected as well as greater than expected readmissions. Thus, a two-tailed test was used. In the example above (3 readmissions out of 40), the probability associated with the left-hand tail was the sum of the probability for 0, 1, 2, or 3 readmissions 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 analysis, the level of significance was set to 0.05.

In the context of the knee and hip replacement report, a Type I error would have occurred when the difference between the actual readmission percent and the expected readmission 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. 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 readmission percent was less than expected, the hospital was assigned the symbol "○" (as shown in the knee and hip replacement report) to indicate that the readmission percent was significantly less than expected.

    ➢ If the actual readmission percent was higher than expected, the hospital was assigned the symbol "●" (as shown in the knee and hip replacement 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 readmission percent and the actual readmission percent was *not* statistically significant. It *cannot be concluded* that the actual readmission percent for that particular hospital was different from the expected readmission percent derived from the particular hospital's risk profile. In this case the hospital was assigned the symbol "☉" (as shown in the knee and hip replacement report).

See Appendix C for an example of calculation of actual and expected readmission rates and logistic regression.

CASE-MIX ADJUSTMENT METHODOLOGY

Charges were adjusted to account for differences in charges across regions of Pennsylvania and hospital variation in the mix of cases across MS-DRGs. Average charges were trimmed for outliers and case-mix adjusted for knee and hip separately. A case-mix adjusted charge is reported for hospitals only when the hospital had 11 or more cases in the analysis after all exclusions were satisfied.

Construction of Reference Database

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

MS-DRG groups were defined as follows:

MS-DRG Group 1	MS-DRG 461	Bilateral or Multiple Major Joint Procedures of Lower Extremity with MCC
	MS-DRG 462	Bilateral or Multiple Major Joint Procedures of Lower Extremity without MCC
MS-DRG Group 2	MS-DRG 469	Major Joint Replacement or Reattachment of Lower Extremity with MCC
MS-DRG Group 3	MS-DRG 470	Major Joint Replacement or Reattachment of Lower Extremity without MCC

Note: MS-DRG groups were the same for both the knee replacement charge analysis and the hip replacement charge analysis.

Trim Methodology

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

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

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

Trim points were determined as follows:

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

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

IQR = $Q3 - Q1$

Lower Trim Point = $Q1 - (3.0 \times IQR)$

Upper Trim Point = $Q3 + (3.0 \times IQR)$

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.

Determining Expected Charges

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

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 charges (Average ActChg) by the average expected charge (Average ExpChg) for the hospital, and then multiplying this quantity by the average charge for the hospital's region:

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

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

DATA TABLES

TABLE 1. STATEWIDE UTILIZATION AND OUTCOME DATA

CY 2013 Data

Total Number of Cases

	#
Knee	35,353
Hip	18,416

30-Day Readmissions

	Cases*	Readmissions	
	#	#	%
Knee	32,394	1,266	3.9%
Hip	15,626	679	4.3%

Average Charge

	# Cases*	Actual Average Charge
Knee	34,152	$52,912
Hip	16,857	$55,493

CY 2012 Data

Average Medicare Fee-for-Service (FFS) Payment

	# Cases*	Actual Average Medicare FFS Payment
Knee	8,504	$12,287
Hip	3,594	$11,827

Average Charge for Medicare Cases

	# Cases*	Actual Average Charge for Medicare Cases
Knee	8,269	$51,537
Hip	3,474	$53,598

* The number of cases in the analysis.

DATA TABLES

TABLE 2. EXCLUSION DATA

Table 2A. 30-Day Readmissions Exclusions – Knee Replacements (CY 2013 Data)

	Cases		30-Day Readmissions	
	#	%	#	%
Total cases before exclusions	35,353	100.0%	–	–
Clinically complex cases excluded[1]	*452*	*1.3%*	–	–
Elective cases (total minus clinically complex)	34,901	98.7%	–	–
Other exclusions			–	–
• *Cases with invalid or missing discharge status*	*1*	*<0.1%*	–	–
• *Patients who left against medical advice*	*9*	*<0.1%*	–	–
• *Patients transferred to another acute care facility*	*98*	*0.3%*	–	–
• *Patients who died during hospitalization in which surgery was performed*	*21*	*0.1%*	–	–
• *Second index hospitalization within 30 days*	*111*	*0.3%*	–	–
• *Cases with invalid data[2]*	*328*	*0.9%*	–	–
• *Out-of-state residents[3]*	*1,939*	*5.5%*	–	–
Total exclusions	*2,959*	*8.4%*	–	–
Total cases remaining in analysis	**32,394**	**91.6%**	**1,266**	**3.9%**

Table 2B. 30-Day Readmissions Exclusions – Hip Replacements (CY 2013 Data)

	Cases		30-Day Readmissions	
	#	%	#	%
Total cases before exclusions	18,416	100.0%	–	–
Clinically complex cases excluded[1]	*1,172*	*6.4%*	–	–
Elective cases (total minus clinically complex)	17,244	93.6%	–	–
Exclusions:			–	–
• *Cases with invalid or missing discharge status*	*0*	*0.0%*	–	–
• *Patients who left against medical advice*	*2*	*<0.1%*	–	–
• *Patients transferred to another acute care facility*	*38*	*0.2%*	–	–
• *Patients who died during hospitalization in which surgery was performed*	*7*	*<0.1%*	–	–
• *Second index hospitalization within 30 days*	*22*	*0.1%*	–	–
• *Cases with invalid data[2]*	*147*	*0.8%*	–	–
• *Out-of-state residents[3]*	*1,402*	*7.6%*	–	–
Total exclusions	*2,790*	*15.1%*	–	–
Total cases remaining in analysis	**15,626**	**84.9%**	**679**	**4.3%**

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[1] Clinically complex cases as defined by the ICD-9-CM codes in Appendix A, Table A1 and cases *not* in the study MS-DRGs (see Appendix A, Table A2 for MS-DRGs not excluded from the study).

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

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

DATA TABLES

TABLE 2. EXCLUSION DATA *CONTINUED*

Table 2C. Average Charge Exclusions – Knee Replacements (CY 2013 Data)

	Cases		Average Charge
	#	**%**	
Total cases before exclusions	35,353	100.0%	$55,024
Exclusions:			
• *Clinically complex cases[1]*	*452*	*1.3%*	*$83,893*
• *Cases in tracheostomy MS-DRG 003*	*1*	*<0.1%*	*–*
• *Cases in low volume MS-DRGs[2]*	*10*	*<0.1%*	*$145,320*
• *Cases that were charge outliers[3]*	*738*	*2.1%*	*$133,741*
Total exclusions	*1,201*	*3.4%*	*–*
Total cases remaining in analysis	**34,152**	**96.6%**	**$52,912**

Table 2D. Average Charge Exclusions – Hip Replacements (CY 2013 Data)

	Cases		Average Charge
	#	**%**	
Total cases before exclusions	18,416	100.0%	$59,240
Exclusions:			
• *Clinically complex cases[1]*	*1,172*	*6.4%*	*$81,592*
• *Cases in tracheostomy MS-DRG 003*	*2*	*<0.1%*	*$904,638*
• *Cases in low volume MS-DRGs[2]*	*6*	*<0.1%*	*$167,806*
• *Cases that were charge outliers[3]*	*379*	*2.1%*	*$150,589*
Total exclusions	*1,559*	*8.5%*	*–*
Total cases remaining in analysis	**16,857**	**91.5%**	**$55,493**

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[1] Clinically complex cases as defined by the ICD-9-CM codes in Appendix A, Table A1 and cases *not* in the study MS-DRGs (See Appendix A, Table A2 for MS-DRS *not* excluded from the study).

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

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

DATA TABLES

TABLE 2. EXCLUSION DATA *CONTINUED*

Exclusions below are for the average charge analysis for 2012 average Medicare fee-for-service payment cases (adult PA residents).

Table 2E. Average Charge Exclusions – Knee Replacements (CY 2012 Data)			
	Cases		**Average Charge**
	#	**%**	
Total cases before exclusions	8,504	100.0%	$53,253
Exclusions:			
• *Cases in low volume MS-DRGs[1]*	*13*	*0.2%*	*$55,826*
• *Cases that were charge outliers[2]*	*222*	*2.6%*	*$117,009*
Total exclusions	*235*	*2.8%*	*–*
Total cases remaining in analysis	**8,269**	**97.2%**	**$51,537**

Table 2F. Average Charge Exclusions – Hip Replacements (CY 2012 Data)			
	Cases		**Average Charge**
	#	**%**	
Total cases before exclusions	3,594	100.0%	$55,508
Exclusions:			
• *Cases in low volume MS-DRGs[1]*	*27*	*0.8%*	*$56,372*
• *Cases that were charge outliers[2]*	*93*	*2.6%*	*$126,573*
Total exclusions	*120*	*3.3%*	*–*
Total cases remaining in analysis	**3,474**	**96.7%**	**$53,598**

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

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

DATA TABLES

TABLE 3. 30-DAY READMISSIONS MODEL FOR KNEE

The c-statistic for the model is 0.65790.

Predictor	Coefficient	Odds Ratio*	p-value
Intercept	-3.9334		
Age (continuous)	0.0017	1.017	0.8636
Age Over 60 (continuous)	0.0429	1.239	0.0006
Female	-0.3134	0.731	<0.0001
Black and Hispanic (all races)	0.4377	1.549	<0.0001
Percent Not Speaking English Very Well (continuous)	0.0271	1.145	0.0026
WBC ≥11.0 10^9/L	0.4431	1.557	0.0006
Chronic Lung Disease	0.5139	1.672	<0.0001
Coronary Artery Disease	0.3149	1.370	<0.0001
Heart Failure	0.6855	1.985	<0.0001
History of Thrombosis or Embolism	0.3454	1.413	0.0043
Long-term (current) Use of Steroids	0.9308	2.536	0.0004
Mental Disorders	0.3557	1.427	<0.0001
Morbid Obesity	0.3698	1.448	<0.0001

* Odds ratio for "Age" is calculated at units of 10, odds ratios for "Age Over 60" is calculated at units of 5, and odds ratio for "Percent Not Speaking English" is calculated at units of 5%. Using "Age Over 60" as an example, the risk for readmission is about 24% higher for patients age 65 than for patients age 60.

TABLE 4. 30-DAY READMISSIONS MODEL FOR HIP

The c-statistic for the model is 0.66893.

Predictor	Coefficient	Odds Ratio*	p-value
Intercept	-3.6304		
Age (continuous)	-0.0072	0.931	0.5616
Age Over 55 (continuous)	0.0458	1.257	0.0026
Black and Hispanic (all races)	0.5740	1.775	<0.0001
Aseptic Necrosis of Knee/Hip Joint	0.4072	1.503	0.0034
Atrial Fibrillation and Flutter	0.4172	1.518	0.0015
Chronic Lung Disease	0.4711	1.602	0.0001
Coronary Artery Disease	0.3356	1.399	0.0014
History of Stroke	0.4686	1.598	0.0056
Long-term (current) Use of Steroids	0.7910	2.206	0.0181
Mental Disorders	0.3689	1.446	<0.0001
Morbid Obesity	0.8233	2.278	<0.0001

* Odds ratio for "Age" is calculated at units of 10 and odds ratio for "Age Over 55" is calculated at units of 5. Using "Age Over 55" as an example, the risk for readmission is about 26% higher for patients age 60 than for patients age 55.

APPENDICES

APPENDIX A: EXCLUSION DEFINITIONS

TABLE A1. CLINICAL COMPLEXITY EXCLUSIONS

Code	Description
Diagnosis (principal diagnosis only)	
170.6	Malignant neoplasm of pelvic bones, sacrum, and coccyx
170.7	Malignant neoplasm of long bones of lower limb
170.9	Malignant neoplasm of bone and articular cartilage, site unspecified
195.3	Malignant neoplasm of pelvis
195.5	Malignant neoplasm of lower limb
198.5	Secondary malignant neoplasm of bone and bone marrow
199.0	Disseminated malignant neoplasm
996.40	Unspecified mechanical complication of internal orthopedic device, implant, and graft
996.41	Mechanical loosening of prosthetic joint
996.42	Dislocation of prosthetic joint
996.43	Broken prosthetic joint implant
996.44	Peri-prosthetic fracture around prosthetic joint
996.45	Peri-prosthetic osteolysis
996.46	Articular bearing surface wear of prosthetic joint
996.47	Other mechanical complication of prosthetic joint implant
996.49	Other mechanical complication of other internal orthopedic device, implant, and graft
996.66	Infection and inflammatory reaction due to internal joint prosthesis
996.67	Infection and inflammatory reaction due to other internal orthopedic device, implant, and graft
996.77	Other complications due to internal joint prosthesis
996.78	Other complications due to other internal orthopedic device, implant, and graft
Diagnosis (any position)	
733.10	Pathological fracture, unspecified site
733.14	Pathological fracture of neck of femur
733.15	Pathological fracture of other specified part of femur
733.19	Pathological fracture of other specified site
733.81	Malunion of fracture
733.82	Nonunion of fracture
733.95	Stress fracture of other bone
733.96	Stress fracture of femoral neck
733.97	Stress fracture of shaft of femur
808.0	Closed fracture of acetabulum
808.1	Open fracture of acetabulum
808.2	Closed fracture of pubis
808.3	Open fracture of pubis
808.41	Closed fracture of ilium
808.42	Closed fracture of ischium
808.43	Multiple closed pelvic fractures with disruption of pelvic circle
808.44	Multiple closed pelvic fractures without disruption of pelvic circle
808.49	Closed fracture of other specified part of pelvis
808.51	Open fracture of ilium
808.52	Open fracture of ischium
808.53	Multiple open pelvic fractures with disruption of pelvic circle
808.54	Multiple open pelvic fractures without disruption of pelvic circle
808.59	Open fracture of other specified part of pelvis
808.8	Unspecified closed fracture of pelvis

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

Code	Description
820.00	Fracture of unspecified intracapsular section of neck of femur, closed
820.01	Fracture of epiphysis (separation) (upper) of neck of femur, closed
820.02	Fracture of midcervical section of neck of femur, closed
820.03	Fracture of base of neck of femur, closed
820.09	Other transcervical fracture of neck of femur, closed
820.10	Fracture of unspecified intracapsular section of neck of femur, open
820.11	Fracture of epiphysis (separation) (upper) of neck of femur, open
820.12	Fracture of midcervical section of neck of femur, open
820.13	Fracture of base of neck of femur, open
820.19	Other transcervical fracture of neck of femur, open
820.20	Fracture of unspecified trochanteric section of femur, closed
820.21	Fracture of intertrochanteric section of femur, closed
820.22	Fracture of subtrochanteric section of femur, closed
820.30	Fracture of unspecified trochanteric section of femur, open
820.31	Fracture of intertrochanteric section of femur, open
820.32	Fracture of subtrochanteric section of femur, open
820.8	Fracture of unspecified part of neck of femur, closed
820.9	Fracture of unspecified part of neck of femur, open
821.00	Fracture of unspecified part of femur, closed
821.01	Fracture of shaft of femur, closed
821.10	Fracture of unspecified part of femur, open
821.11	Fracture of shaft of femur, open
821.20	Fracture of lower end of femur, unspecified part, closed
821.21	Fracture of femoral condyle, closed
821.22	Fracture of lower epiphysis of femur, closed
821.23	Supracondylar fracture of femur, closed
821.29	Other fracture of lower end of femur, closed
821.30	Fracture of lower end of femur, unspecified part, open
821.31	Fracture of femoral condyle, open
821.32	Fracture of lower epiphysis of femur, open
821.33	Supracondylar fracture of femur, open
821.39	Other fracture of lower end of femur, open
Procedures (any position)	
00.70	Revision of hip replacement, both acetabular and femoral components
00.71	Revision of hip replacement, acetabular component
00.72	Revision of hip replacement, femoral component
00.73	Revision of hip replacement, acetabular liner and/or femoral head only
00.80	Revision of knee replacement, total (all components)
00.81	Revision of knee replacement, tibial component
00.82	Revision of knee replacement, femoral component
00.83	Revision of knee replacement, patellar component
00.84	Revision of total knee replacement, tibial insert (liner)
00.85	Resurfacing hip, total, acetabulum and femoral head
00.86	Resurfacing hip, partial, femoral head
00.87	Resurfacing hip, partial, acetabulum
78.65	Removal of implanted devices from bone, femur
78.66	Removal of implanted devices from bone, patella

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

Code	Description
78.67	Removal of implanted devices from bone, tibia and fibula
80.05	Arthrotomy for removal of prosthesis without replacement, hip
80.06	Arthrotomy for removal of prosthesis without replacement, knee
80.09	Arthrotomy for removal of prosthesis without replacement, other specified sites
81.52	Partial hip replacement
81.53	Revision of hip replacement, NOS
81.55	Revision of knee replacement, NOS
81.59	Revision of joint replacement of lower extremity, not elsewhere classified

TABLE A2. MS-DRG CRITERIA FOR ELECTIVE KNEE AND HIP REPLACEMENT
STUDY POPULATION DEFINITION

MS-DRGs *Not* Excluded from the Study

MS-DRG 003	ECMO or Tracheostomy with Mechanical Ventilation 96+ Hours or Principal Diagnosis Except Face, Mouth, Neck with Major O.R.
MS-DRG 461	Bilateral or Multiple Major Joint Procedures of Lower Extremity with MCC
MS-DRG 462	Bilateral or Multiple Major Joint Procedures of Lower Extremity without MCC
MS-DRG 463	Wound Debridement and Skin Graft Except Hand, for Musculo-Connective Tissue Disorders with MCC
MS-DRG 464	Wound Debridement and Skin Graft Except Hand, for Musculo-Connective Tissue Disorders with CC
MS-DRG 465	Wound Debridement and Skin Graft Except Hand, for Musculo-Connective Tissue Disorders without CC/MCC
MS-DRG 469	Major Joint Replacement or Reattachment of Lower Extremity with MCC
MS-DRG 470	Major Joint Replacement or Reattachment of Lower Extremity without MCC

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

Potential Risk Factor	ICD-9-CM Codes (in any diagnosis/procedure position unless noted otherwise)
Alcohol-related Disorders	291.0, 291.1, 291.2, 291.3, 291.5, 291.81, 291.82, 291.89, 291.9, 303.00, 303.01, 303.02, 303.90, 303.91, 303.92, 305.00, 305.01, 305.02
Anemia	280.1, 280.8, 280.9, 281.0, 281.1, 281.2, 281.3, 281.4, 281.8, 281.9, 282.0, 282.1, 282.2, 282.3, 282.40, 282.41, 282.42, 282.43, 282.44, 282.45, 282.46, 282.47, 282.49, 282.5, 282.60, 282.61, 282.62, 282.63, 282.64, 282.68, 282.69, 282.7, 282.8, 282.9, 283.0, 283.10, 283.11, 283.19, 283.2, 283.9, 284.01, 284.09, 284.11, 284.12, 284.19, 284.2, 284.81, 284.89, 284.9, 285.0, 285.21, 285.22, 285.29, 285.3, 285.8
Arthritis, Infective	711.05, 711.06, 711.95, 711.96, 730.15, 730.16
Arthritis, Rheumatoid and Inflammatory Joint Disease	696.0, 714.0, 714.1, 714.2, 714.30, 714.31, 714.32, 714.33, 714.4, 714.89, 714.9
Aseptic Necrosis of Knee/Hip Joint	733.42, 733.43
Asthma	493.00, 493.01, 493.02, 493.10, 493.11, 493.12, 493.90, 493.91, 493.92
Atrial Fibrillation and Flutter	427.31, 427.32
Cancer	140.0-209.36, 209.70-209.79, 230.0-239.9
Cardiomyopathy	425.0, 425.11, 425.18, 425.3, 425.4, 425.5, 425.7, 425.8, 425.9, 429.1, 429.3
Cerebrovascular Disease	433.00, 433.10, 433.20, 433.30, 433.80, 433.90, 434.00, 434.10, 434.90, 436, 437.0, 437.1, 437.2, 437.3, 437.4
Chronic Deep Vein Thrombosis Lower Extremity	453.50, 453.51, 453.52
Chronic Kidney Disease	403.00, 403.01, 403.10, 403.11, 403.90, 403.91, 404.00, 404.02, 404.10, 404.12, 404.90, 404.92, 585.1, 585.2, 585.3, 585.4, 585.5, 585.6, 585.9, V45.11
Chronic Lung Disease	491.0, 491.1, 491.20, 491.21, 491.22, 491.8, 491.9, 492.0, 492.8, 493.20, 493.21, 493.22, 494.0, 494.1, 496, 500, 501, 502, 503, 504, 505, 506.4, 508.1, 515, 516.31, 516.32, 516.34, 518.2, 518.83
Chronic Pulmonary Embolism	416.2
Chronic Pulmonary Heart Disease	416.0, 416.1, 416.8, 416.9
Coagulopathy	286.0, 286.1, 286.2, 286.3, 286.4, 287.30, 287.31, 287.32, 287.33, 287.39, 289.81
Cognitive Impairment	290.0, 290.10, 290.11, 290.12, 290.13, 290.20, 290.21, 290.3, 290.40, 290.41, 290.42, 290.43, 290.8, 290.9, 294.20, 294.21, 294.8, 294.9, 310.0, 310.1, 310.2, 310.81, 310.89, 310.9, 317, 318.0, 318.1, 318.2, 319, 331.83, V15.52
Congenital Anomaly	740.0, 740.1, 740.2, 741.00, 741.01, 741.02, 741.03, 741.90, 741.91, 741.92, 741.93, 742.0, 742.1, 742.2, 742.3, 742.4, 742.51, 742.53, 742.59, 742.8, 742.9, 745.0, 745.10, 745.11, 745.12, 745.19, 745.2, 745.3, 745.4, 745.5, 745.60, 745.61, 745.69, 745.7, 745.8, 745.9, 746.01, 746.02, 746.09, 746.1, 746.2, 746.3, 746.4, 746.5, 746.6, 746.7, 746.81, 746.82, 746.83, 746.84, 746.85, 746.86, 746.87, 746.89, 746.9, 747.0, 747.10, 747.11, 747.20, 747.21, 747.22, 747.29, 747.31, 747.32, 747.39, 747.40, 747.41, 747.42, 747.49, 747.5, 747.60, 747.61, 747.62, 747.63, 747.64, 747.69, 747.81, 747.82, 747.83, 747.89, 747.9, 748.3, 748.4, 748.5, 748.60, 748.61, 748.69, 748.8, 748.9, 751.0, 751.1, 751.2, 751.3, 751.4, 751.5, 751.60, 751.61, 751.62, 751.69, 751.7, 751.8, 751.9, 753.0, 753.10, 753.11, 753.12, 753.13, 753.14, 753.15, 753.16, 753.17, 753.19, 753.20, 753.21, 753.22, 753.23, 753.29, 753.3, 753.4, 753.5, 753.6, 753.7, 753.8, 753.9, 758.0, 758.1, 758.2, 758.31, 758.32, 758.33, 758.39, 758.4, 758.5, 758.6, 758.7, 758.81, 758.89, 758.9, 759.7, 759.81, 759.82, 759.83, 759.89, 759.9, 760.71, 760.72, 760.73, 760.75, 760.76, 760.77, 760.78, 771.0, 771.1, 775.1

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

Potential Risk Factor	ICD-9-CM Codes (in any diagnosis/procedure position unless noted otherwise)
Coronary Artery Disease	412, 414.00, 414.01, 414.02, 414.03, 414.04, 414.05, 414.06, 414.07, 414.2, 414.3, 414.4, 414.8, 414.9, 429.2
Crohn's Disease and Regional Enteritis	555.0, 555.1, 555.2, 555.9, 556.0, 556.1, 556.2, 556.3, 556.4, 556.5, 556.6, 556.8, 556.9
Deformity of Knee/Hip Joint, Acquired	736.30, 736.31, 736.32, 736.39, 736.41, 736.42, 736.5, 736.6, 736.81
Deformity of Musculoskeletal System, Congenital	754.2, 754.30, 754.31, 754.32, 754.33, 754.35, 754.40, 754.41, 754.42, 754.43, 754.44, 754.50, 754.51, 754.52, 754.53, 754.59, 755.60, 755.61, 755.62, 755.63, 755.64, 755.65, 755.66, 755.67, 755.69
Deformity of Spine, Acquired	737.10, 737.11, 737.12, 737.19, 737.20, 737.21, 737.22, 737.29, 737.30, 737.31, 737.32, 737.33, 737.34, 737.39, 737.40, 737.41, 737.42, 737.43, 737.8, 737.9
Degenerative Diseases of Musculoskeletal System	718.55, 718.56, 720.0, 720.1, 720.2, 720.81, 720.89, 720.9, 721.0, 721.1, 721.2, 721.3, 721.41, 721.42, 721.5, 721.6, 721.7, 721.8, 721.90, 721.91
Diabetes	249.00, 249.01, 249.10, 249.11, 249.20, 249.21, 249.30, 249.31, 249.40, 249.41, 249.50, 249.51, 249.60, 249.61, 249.70, 249.71, 249.80, 249.81, 249.90, 249.91, 250.00, 250.01, 250.02, 250.03, 250.10, 250.11, 250.12, 250.13, 250.20, 250.21, 250.22, 250.23, 250.30, 250.31, 250.32, 250.33, 250.40, 250.41, 250.42, 250.43, 250.50, 250.51, 250.52, 250.53, 250.60, 250.61, 250.62, 250.63, 250.70, 250.71, 250.72, 250.73, 250.80, 250.81, 250.82, 250.83, 250.90, 250.91, 250.92, 250.93
Diseases of Bone and Cartilage	730.70, 731.0, 731.1, 731.3, 731.8, 732.1, 732.4, 732.7, 732.8, 732.9
Diseases of Central Nervous System, Hereditary/Degenerative	330.1, 330.2, 330.3, 330.8, 330.9, 331.0, 331.11, 331.19, 331.2, 331.3, 331.4, 331.5, 331.6, 331.7, 331.81, 331.82, 331.89, 331.9, 332.0, 333.0, 333.4, 333.5, 333.6, 334.0, 334.1, 334.2, 334.3, 334.4, 334.8, 334.9, 335.0, 335.10, 335.11, 335.19, 335.20, 335.21, 335.22, 335.23, 335.24, 335.29, 335.8, 335.9, 336.0, 336.1, 336.2, 336.3, 336.8, 336.9, 337.20, 337.21, 337.22, 337.29, 337.3, 337.9, 340, 341.0, 341.1, 341.8, 341.9
Diseases of Knee/Hip Joint	094.0, 274.00, 274.01, 274.02, 274.03, 713.5, 716.15, 716.16, 716.55, 716.56, 716.85, 716.86, 716.95, 716.96
Disorders of Joint, Muscle, and Ligament	718.35, 718.36, 718.45, 718.46, 726.5, 726.60, 726.61, 726.62, 726.63, 726.64, 726.65, 726.69, 728.2, 728.3, 728.4, 728.5, 728.87
Drug-related Disorders	292.0, 292.11, 292.12, 292.2, 292.81, 292.82, 292.83, 292.84, 292.85, 292.89, 292.9, 304.00, 304.01, 304.02, 304.10, 304.11, 304.12, 304.20, 304.21, 304.22, 304.30, 304.31, 304.32, 304.40, 304.41, 304.42, 304.50, 304.51, 304.52, 304.60, 304.61, 304.62, 304.70, 304.71, 304.72, 304.80, 304.81, 304.82, 304.90, 304.91, 304.92, 305.20, 305.21, 305.22, 305.30, 305.31, 305.32, 305.40, 305.41, 305.42, 305.50, 305.51, 305.52, 305.60, 305.61, 305.62, 305.70, 305.71, 305.72, 305.80, 305.81, 305.82, 305.90, 305.91, 305.92
Functional Impairment	780.72, 781.2, 781.3, V15.88, V46.3
Heart Failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40, 428.41, 428.42, 428.43, 428.9
Heart Valve Disease	394.0, 394.1, 394.2, 394.9, 395.0, 395.1, 395.2, 395.9, 396.0, 396.1, 396.2, 396.3, 396.8, 396.9, 397.0, 397.1, 424.0, 424.1, 424.2, 424.3
History of Cancer	V10.00, V10.01, V10.02, V10.03, V10.04, V10.05, V10.06, V10.07, V10.09, V10.11, V10.12, V10.20, V10.21, V10.22, V10.29, V10.3, V10.40, V10.41, V10.42, V10.43, V10.44, V10.45, V10.46, V10.47, V10.48, V10.49, V10.50, V10.51, V10.52, V10.53, V10.59, V10.60, V10.61, V10.62, V10.63, V10.69, V10.71, V10.72, V10.79, V10.81, V10.82, V10.83, V10.84, V10.85, V10.86, V10.87, V10.88, V10.89, V10.90, V10.91

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

Potential Risk Factor	ICD-9-CM Codes (in any diagnosis/procedure position unless noted otherwise)
History of Coronary and Valve Procedures	V42.2, V43.3, V45.81, V45.82
History of Lower Extremity Amputation	V49.70, V49.71, V49.72, V49.73, V49.74, V49.75, V49.76, V49.77
History of Pacemaker or Defibrillator	V45.01, V45.02, V53.31, V53.32, V53.39
History of Stroke	438.0, 438.10, 438.11, 438.12, 438.13, 438.14, 438.19, 438.20, 438.21, 438.22, 438.30, 438.31, 438.32, 438.40, 438.41, 438.42, 438.50, 438.51, 438.52, 438.53, 438.6, 438.7, 438.81, 438.82, 438.83, 438.84, 438.85, 438.89, 438.9, V12.54
History of Thrombosis or Embolism	V12.51, V12.55
Hypertension, Essential	401.1, 401.9
Hypertension, Malignant and Secondary	401.0, 402.00, 402.10, 402.90, 405.01, 405.09, 405.11, 405.19, 405.91, 405.99
Immunity Disorder	042, 279.00, 279.01, 279.02, 279.03, 279.04, 279.05, 279.06, 279.09, 279.10, 279.11, 279.12, 279.13, 279.19, 279.2, 279.3, 279.41, 279.49, 279.50, 279.51, 279.52, 279.53, 279.8, 279.9, 710.0, 710.1, V42.0, V42.1, V42.6, V42.7, V42.81, V42.82, V42.83, V42.84, V42.89, V42.9 Principal diagnosis: 996.80, 996.81, 996.82, 996.83, 996.84, 996.85, 996.86, 996.87, 996.88, 996.89 Procedures prior to knee/hip replacement: 00.18, 33.50, 33.51, 33.52, 33.6, 37.51, 37.52, 37.53, 41.00, 41.01, 41.02, 41.03, 41.04, 41.05, 41.06, 41.07, 41.08, 41.09, 41.94, 46.97, 50.51, 50.59, 52.80, 52.81, 52.82, 52.83, 52.85, 52.86, 55.69
Liver Disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.70, 070.71, 456.0, 456.1, 456.20, 456.21, 571.0, 571.1, 571.2, 571.3, 571.40, 571.41, 571.42, 571.49, 571.5, 571.6, 571.8, 571.9, 572.3, 572.4, 572.8, 573.0, 573.1, 573.2, 573.3, 573.4, 573.5, 573.8, 573.9
Long-term (current) Use of Antiplatelets and Antithrombotics	V58.61, V58.63
Long-term (current) Use of Insulin	V58.67
Long-term (current) Use of Steroids	V58.65
Lower Extremity Ulcer	707.10, 707.11, 707.12, 707.13, 707.14, 707.15, 707.19
Malnutrition	261, 262, 263.0, 263.1, 263.2, 263.8, 263.9, 799.4, V85.0
Mental Disorders	295.00-295.95, 296.00-296.99, 297.0, 297.1, 297.2, 297.3, 297.8, 297.9, 298.0, 298.1, 298.4, 298.8, 298.9, 299.00, 299.01, 299.10, 299.11, 299.80, 299.81, 299.90, 299.91, 300.00, 300.01, 300.02, 300.09, 300.10, 300.11, 300.12, 300.13, 300.14, 300.15, 300.16, 300.19, 300.20, 300.21, 300.22, 300.23, 300.29, 300.3, 300.4, 300.5, 300.6, 300.7, 300.81, 300.82, 300.89, 300.9, 301.0, 301.10, 301.11, 301.12, 301.13, 301.20, 301.21, 301.22, 301.3, 301.4, 311
Morbid Obesity	278.01, V85.39, V85.41, V85.42, V85.43, V85.44, V85.45
Multiple Total Knee and/or Hip Replacement	81.51, 81.54
Muscular Dystrophy	359.0, 359.1, 359.21, 359.22, 359.23, 359.29
Myasthenia/Myoneural Disorders	358.00, 358.01, 358.1, 358.30, 358.31, 358.39, 358.8, 358.9
Obesity	278.00, V85.30, V85.31, V85.32, V85.33, V85.34, V85.35, V85.36, V85.37, V85.38, V85.54
Obstructive Sleep Apnea and Obesity-Related Hypoventilation Syndrome	278.03, 327.23
Osteoporosis	733.00, 733.01, 733.02, 733.03, 733.09

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

Potential Risk Factor	ICD-9-CM Codes (in any diagnosis/procedure position unless noted otherwise)
Oxygen Therapy Dependence (long-term)	V46.2
Paralysis and Palsy	138, 342.00, 342.01, 342.02, 342.10, 342.11, 342.12, 342.80, 342.81, 342.82, 342.90, 342.91, 342.92, 343.0, 343.1, 343.2, 343.3, 343.4, 343.8, 343.9, 344.00, 344.01, 344.02, 344.03, 344.04, 344.09, 344.1, 344.2, 344.30, 344.31, 344.32, 344.40, 344.41, 344.42, 344.5, 344.89, 344.9
Peripheral Vascular Disease	440.0, 440.1, 440.20, 440.21, 440.22, 440.23, 440.24, 440.29, 440.30, 440.31, 440.32, 440.4, 440.8, 440.9, 441.2, 441.4, 441.7, 441.9, 442.0, 442.1, 442.2, 442.3, 442.82, 442.83, 442.84, 443.0, 443.1, 443.81, 443.82, 443.89, 443.9, 447.70, 447.71, 447.72, 447.73, 453.71, 453.72, 453.73, 453.74, 453.75, 453.76, 453.77, 453.79, 454.0, 454.1, 454.2, 454.8, 454.9, 459.30, 459.31, 459.32, 459.33, 459.39, 459.81, 557.1, 593.81
Polyneuropathy	356.0, 356.1, 356.2, 356.3, 356.4, 356.8, 356.9, 357.1, 357.2, 357.3, 357.4, 357.5, 357.81
Visual Impairment	369.00, 369.01, 369.02, 369.03, 369.04, 369.05, 369.06, 369.07, 369.08, 369.10, 369.11, 369.12, 369.13, 369.14, 369.15, 369.16, 369.17, 369.18, 369.20, 369.21, 369.22, 369.23, 369.24, 369.25, 369.3, 369.4, 369.60, 369.61, 369.62, 369.63, 369.64, 369.65, 369.66, 369.67, 369.68, 369.69, 369.70, 369.71, 369.72, 369.73, 369.74, 369.75, 369.76, 369.8, 369.9

APPENDIX C: EXAMPLE OF LOGISTIC REGRESSION

Calculations Used in Determining Expected Readmission Rates for a Given Hospital
Knee Replacement

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

Actual Percent Readmissions: Total number of cases readmitted / total number of hospitalizations.

Expected Percent Readmissions: Mean of the predicted probability of readmission for each hospitalization.

Step 1: Calculate the predicted probability of readmission for each hospitalization (PReadmit):

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

$$= -3.9334 + 0.0017 \text{ (Age)} + 0.0429 \text{ (Age Over 60)} + \ldots + 0.4431 \text{ (WBC} \geq 11.0 \; 10^9 \text{L)} + \ldots + 0.9308 \text{ (Long-term (current) Use of Steroids)} + \text{coefficient (other variables in knee readmission model)} + \ldots$$

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

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

where $e \approx 2.7182818285$

Step 2: Calculate the mean probability of readmission (PReadmit) for each hospital (expected percent of readmissions)

$$\text{PReadmit} = \frac{\Sigma \, \text{PReadmit}}{n}$$

APPENDIX D: EXAMPLE OF CASE-MIX ADJUSTMENT

Region 1 – Southwestern PA
Knee Replacement

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

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

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

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

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

Region 1 - Southwestern PA and MS-DRG 461 or 462: $69,809.13
or
Region 1 - Southwestern PA and MS-DRG 469: $62,871.97
or
Region 1 - Southwestern PA and MS-DRG 470: $46,627.97

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

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

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