

TOTAL HIP AND KNEE REPLACEMENTS

FISCAL YEAR 2002 DATA

July 1, 2001 through June 30, 2002

TECHNICAL NOTES

**The Pennsylvania Health Care Cost Containment Council
April 2005**

Preface

This document serves as a technical supplement to the *Total Hip and Knee Replacements* report (Fiscal Year 2002: July 1, 2001 to June 30, 2002). The *Technical Notes* describes the methodology of the analyses and outlines the development of the report format and presentation. This document also includes data tables containing information about the statewide results, cases excluded from analysis, and risk-adjustment models. The report presents information regarding the care received by adult (≥ 18 years of age) patients who elected to undergo total hip replacements or knee replacements.

Measures reported for hospitals with 30 or more cases:

- *Risk-adjusted measures for total hip and knee replacements combined—*
 - *Deep Joint Infection or Device Problem Rating*
 - *Blood Clot Lung/Leg Rating*
 - *Wound Infection Rating*
 - *Readmission Rating*
 - *Post-Operative Length of Stay (in days)*
- *Average Hospital Charge for Total Hip Replacements (hospitals with at least 5 total hip replacement cases)*
- *Average Hospital Charge for Knee Replacements (hospitals with at least 5 knee replacement cases)*

Measures reported for surgeons with 30 or more cases:

- *Risk-adjusted measures for total hip and knee replacements combined—*
 - *Deep Joint Infection or Device Problem Rating*
 - *Blood Clot Lung/Leg Rating*
 - *Readmission Rating*
 - *Post-Operative Length of Stay (in days)*

The rigorous methodology described in this document was developed to ensure the appropriate assignment of complications to hospitals and surgeons and to account for the differences among individual patients that had the potential to influence the outcome of an elective total hip or knee replacement surgery.

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DATA COLLECTION AND VERIFICATION

The Pennsylvania Health Care Cost Containment Council (PHC4) is mandated by state law to collect and disseminate health care data. The data for the *Total Hip and Knee Replacements* report (FY2002) were submitted electronically on a quarterly basis to PHC4 by Pennsylvania general acute care (GAC) and specialty GAC hospitals as directed by the data submission requirements of Act 89 of 1986 (currently Act 14 of 2003). The data included demographic information, hospital charges, and diagnosis and procedure codes using the ICD-9-CM (International Classification of Diseases, Ninth Revision, Clinical Modification).

Hospital and Orthopedic Surgeon Verification of Data

Hospitals were requested to confirm the accuracy of the data, provide five additional diagnoses and three additional procedure codes as appropriate, and confirm that all cases had the correct surgeon assignment. Surgeons were requested to perform a patient level review of the submitted records and then attest to the accuracy of the data and the surgeon assignment. During the initial verification process, hospital and surgeon verification was limited to the data associated with the hospitalization in which the total hip or knee replacement surgery was performed.

After the initial assignment of complications, in order to ensure that the assignment of complications was correct, surgeons and hospitals were asked to provide additional information for complications identified in the original hospitalization in which the total hip or knee replacement was performed. Surgeons were also asked to review the complications identified during a subsequent hospitalization and discuss any revisions with the appropriate hospital staff. Hospital staff was asked to provide the additional information and to verify the accuracy of reported codes for complications identified during a readmission.

The assignment of complications was then updated to reflect the surgeon and hospital responses. If a surgeon or hospital did not respond to the request for additional data, it was assumed that the initial assignment of complications was correct.

Chart Audit

Accurate coding was critical to the development of a physician-level report for total hip or knee replacement and was especially important for the correct assessment of post-surgical complications. To ensure the quality of the report, PHC4 contracted with an independent auditing company to determine the reliability of PHC4's administrative data. A sample of 300 cases was randomly selected from the total hip or knee replacements study population. To be certain of the accuracy of the chart review, PHC4 required an inter-rater reliability study as part of the audit. The inter-rater reliability study demonstrated an accuracy rate of 99%. Overall, there was 90% agreement on all principal and secondary diagnoses and procedures. The audit results also demonstrated 5.4% over-coding and 13.2% under-coding for the secondary diagnoses, and 6.7% over-coding and 16.9% under-coding for the secondary procedures. Based on the complication definitions for the total hip and knee replacement project, hospitals submitted a total of 20 codes, all of which were matched to the auditors' results. The auditors identified four additional complication codes that were not submitted to PHC4 by the hospitals.

STUDY POPULATION

Inclusion Criteria

The study population was drawn from all Pennsylvania general acute care (GAC) and specialty GAC hospital discharges during FY2002 (July 1, 2001 through June 30, 2002). Discharge records included in the study had one of the following ICD-9-CM codes present as either a principal or secondary procedure:

- 81.51 Total Hip Replacement
- 81.54 Knee Replacement

Standard Exclusion Criteria

To ensure a clinically cohesive study population that included elective total hip or knee replacements and to adequately risk adjust for hospitals and surgeons, cases meeting the inclusion criteria outlined above were examined for atypical characteristics including those that placed the patient at a high risk of complications. In doing so, cases meeting any one of the following criteria were excluded from the study (see Data Table 2 for exclusion data):

- Unverified cases: Cases from hospitals that closed after the initial verification process and prior to PHC4's request to hospitals and surgeons for additional data (see *Hospital and Orthopedic Surgeon Verification of Data*).
- Age < 18 years
- Clinically complex cases:
 - The discharge record was not assigned to one of the following DRGs:
 - DRG 209: Major Joint And Limb Reattachment Procedures of Lower Extremity
 - DRG 471: Bilateral Or Multiple Major Joint Procedures of Lower Extremity
 - DRG 483: Tracheostomy Except for Face, Mouth and Neck Diagnoses.
 - Revisions: For total hip replacements, a hip revision procedure¹ was the principal procedure, performed on the same day, or prior to the total hip replacement. For knee replacements, a knee revision procedure² was the principal procedure, performed on the same day, or prior to the knee replacement.
 - A partial hip replacement³ was performed anytime during the same hospitalization.
 - Total hip and knee replacements were performed during the same hospitalization.
 - Any one of the following diagnoses was present:
 - Complication from a prior orthopedic surgery⁴
 - Bone cancer⁵
 - Fracture of hip/knee⁶
 - Joint infection of hip/knee⁷
 - Special request for exclusion: Cases were excluded based on the special requests submitted by hospitals and/or surgeons.
- The record contains invalid data for linkage (e.g., invalid social security number, admission date, discharge date, birth date, or sex).
- The patient left the hospital against medical advice.
- The patient died during the hospitalization in which the total hip or knee replacement was performed.

¹ Procedure code of 81.53.

² Procedure code of 81.55.

³ Procedure code of 81.52.

⁴ Principal diagnosis of 996.4, 996.77, or 996.78.

⁵ Principal or secondary diagnosis of 170.0, 170.1, 170.2, 170.3, 170.4, 170.5, 170.6, 170.7, 170.8, 170.9, or 198.5.

⁶ Principal diagnosis for hip: 733.14, 733.15, 733.81, 733.82, 808.0, 808.1, 820.00, 820.01, 820.02, 820.03, 820.09, 820.10, 820.11, 820.12, 820.13, 820.19, 820.20, 820.21, 820.22, 820.30, 820.31, 820.32, 820.8, 820.9, 821.00, 821.01, 821.10, or 821.11; principal diagnosis for knee: 733.16, 733.81, 733.82, 821.20, 821.21, 821.22, 821.23, 821.29, 821.30, 821.31, 821.32, 821.33, 821.39, 822.0, 822.1, 823.00, 823.01, 823.02, 823.10, 823.11, 823.12, 823.20, 823.21, 823.22, 823.30, 823.31, 823.32, 823.80, 823.81, 823.82, 823.90, 823.91, or 823.92

⁷ Principal diagnosis for hip: 730.05, 730.15, 730.25, 730.35, 730.95, 711.05, 711.95, 996.66, or 996.67; principal diagnosis for knee: 730.06, 730.16, 730.26, 730.36, 730.96, 711.06, 711.96, 996.66, or 996.67.

Cases Excluded from the Analysis of a Specific Measure

In addition to the standard exclusions, individual cases were excluded from post-operative length of stay and average hospital charge analyses when the data in the record was insufficient or inappropriate to the measure of interest. For post-operative length of stay, cases with a tracheostomy (DRG 483) and/or a post-operative length of stay of less than 1 day or greater than 21 days were excluded. For average hospital charge, records with a tracheostomy (DRG 483), an invalid charge (e.g., < \$5,000), and/or charge outliers were excluded.

UTILIZATION AND OUTCOME MEASURE ANALYSES

Definition of Measures

Risk-Adjusted Complications

Deep Joint Infection or Device Problem

Blood Clot Leg/Lung

Wound Infection

A complication was defined by one of the select group of ICD-9-CM codes listed in Appendix A. Complications could occur during the initial hospitalization in which the surgery was performed **and/or** during a subsequent readmission. All complications were verified by hospitals/surgeons. The process for identification of complications in each setting is described below:

- *Initial hospitalization during which the surgery was performed:* Complications were identified by secondary diagnosis and procedure codes. For deep joint infection or device problem—if the complication was identified by a procedure code, the procedure date had to occur after the total hip or knee replacement date.
- *Readmission (inpatient GAC and specialty GAC only):* Complications were identified by the principal diagnosis and the principal and secondary procedure codes. For complications identified during a readmission, a complication was counted when a deep joint infection or device problem occurred within 365 days of the surgery, a blood clot occurred within 45 days of the surgery, and/or a wound infection occurred within 30 days of the surgery.

Risk-Adjusted Readmission

A hospital readmission was defined as an admission to **any** Pennsylvania GAC or specialty GAC hospital, for any reason, except for patients admitted for rehabilitation (DRG 462). The readmission must have occurred within 1-30 days of the discharge date of the initial total hip or knee replacement hospitalization. To avoid possible confusion with transfer cases, same day readmissions were not counted. Because this report focuses on elective total hip and knee replacements, *any* readmission to an acute care hospital was counted in this measure. Readmissions may be planned or unplanned. However, whether the readmission is planned or unplanned cannot be distinguished in the data submitted to PHC4. See Data Table 9 for readmission frequency data, by reason for readmission.

Risk-Adjusted Post-Operative Length of Stay

Post-operative length of stay measured how long, on average, patients stayed in the hospital following joint replacements (only the hospitalization in which the total hip or knee replacement was performed was included).

Average Hospital Charge

Average charge was reported for hospitals only. The average charge was the patient's total charge excluding professional fees (e.g., physician fees) for the hospitalization in which the total hip or knee replacement was performed. Note that while charges are a standard way of reporting data, they do not reflect the actual cost of treatment, nor do they reflect the payment that the hospital may have actually received. See the "Methodology for Analysis of Average Hospital Charge" section.

Methodology for Analysis of Risk-Adjusted Measures

The determination of the reported risk-adjusted outcomes involved several different calculations—actual values, expected values, statistical ratings, and risk-adjusted values. Actual numbers were determined for deep joint infection or device problem, blood clot lung/leg, wound infection, and readmission. Actual post-operative length of stay was calculated in days. Actual results for each hospital/surgeon were then adjusted for clinical or demographic risk inherent in a particular hospital's/surgeon's case profile. The hospital's or surgeon's risk profile was then used to calculate the expected values for each measure. For deep joint infection or device problem, blood clot lung/leg, wound infection, and readmission, significance tests were conducted to determine if the difference between a hospital's/surgeon's actual and expected values was too large to be attributed solely to chance. (*Note: Wound infection was reported only at the hospital level.*) These results are displayed as ratings. For post-operative length of stay the actual and expected values were the bases for the risk-adjusted values displayed in the report.

The methodology for each of these calculations is described in the following paragraphs.

Determining Actual (Observed) Values for hospitals and surgeons

Deep Joint Infection or Device Problem	The total number of cases with a deep joint infection or device problem.
Blood Clot Lung/Leg	The total number of cases with a blood clot in the lung or leg.
Wound Infection	The total number of cases with a wound infection.
Readmission	The total number of patients readmitted at least once within 1-30 days of the date of discharge from the hospitalization in which the replacement was performed.
Average Post-Operative Length of Stay in days	The post-operative length of stay for a hospitalization was determined by subtracting the surgery date from the discharge date. The average post-operative length of stay for a hospital/surgeon was determined as the arithmetic mean length of stay for the cases included in the post-operative length of stay analysis.

Determining Expected (Predicted) Values

Risk Adjustment Procedures

Risk-adjustment models were constructed to account for differences among individual patients that had the potential to influence the outcome of total hip or knee replacement. Binary logistic regression techniques were used to build models for deep joint infection or device problem, blood clot lung/leg, wound infection, and readmission. Linear regression techniques were used to construct the post-operative length of stay model. Risk-adjustment models were developed for each measure. Each model used significant risk factors to calculate expected, or predicted, results for each patient.

Building the risk-adjustment models involved several steps—identification of potential risk factors, model selection, cross-validation, and calculation of model adequacy.

Potential Risk Factors

The potential risk factors considered included the clinical, demographic, and socioeconomic factors identified in the literature, and the *Atlas Outcomes™* Predicted Length of Stay (MQPredLOS). The MQPredLOS was an important enhancement to the models because it is based on the examination of numerous Key Clinical Findings (KCFs) such as lab tests, EKG readings, vital signs, the patient's medical history, imaging results, pathology, and

operative/endoscopy findings—items that are not typically available in an administrative database. Those factors that demonstrated a potential to contribute to the outcome of the event were identified as candidate variables. See Appendix B for descriptions of the candidate variables.

Model Selection

Model selection identified those candidate variables that were statistically significant predictors of the relevant event (i.e., deep joint infection or device problem, blood clot lung/leg, wound infection, readmission, and post-operative length of stay). After cases to be excluded from a particular analysis were removed, the remaining cases were randomly split into two equal-size samples—a development sample and a cross-validation sample. Regression techniques were then used to identify the candidate variables that were statistically significant predictors.

Using the cases in the development sample, backwards-stepwise logistic regression models were constructed for deep joint infection or device problem, blood clot lung/leg, wound infection, and readmission. In the development of the models, all tests of significance ($p < 0.10$) were based on the likelihood ratio.

Because length of stay is a continuous variable, rather than a binary one, a general linear modeling approach was used for the post-operative length of stay model. The model was constructed using the development sample. All tests of significance were based on general linear model F-tests. A $p < 0.10$ model was built for more liberal identification of risk factors.

The selection of variables for the final models was based on the results of the development sample. Findings (significant or not significant) for each of the candidate variables tested in the development models are displayed in Data Table 3. See Data Table 4 for the p values of the significant variables in the development sample. See Data Table 6 for statewide frequencies for each candidate variable tested.

Cross-Validation

The cross validation process re-estimated the model built in the model selection process using only the variables that were significant in the development sample to determine which factors remained significant in the cross-validation sample.

Measures of Model Adequacy

To evaluate model performance the following measures were considered:

c Statistic The measure of “goodness of fit” used to describe the logistic regression models is the *c* statistic, which 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 .5 and 1, with higher values associated with better discrimination. In some respects, the *c* statistic is similar to the R^2 commonly used in linear regression. Both *c* and R^2 approach 1 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 each model are as follows:

<u><i>Measure</i></u>	<u><i>c</i> Statistic</u>
Deep Joint Infection or Device	0.613
Blood Clot Lung/Leg	0.561
Wound Infection	0.607
Readmission	0.618

R-square: Coefficient of Determination (R^2) was used to evaluate the performance of the linear regression model. It refers to the percentage of the total variability among patients that can be explained by the estimated model involving the specified risk factors.

<u>Measure</u>	<u>R-square</u>
Post-Operative Length of Stay	7.3%

Coefficients and Odds Ratios

The coefficients and odds ratios associated with the risk factors retained in the final model are listed on Data Table 5. The entire data set was used to create the final coefficients (i.e., the development sample and the cross-validation sample were “recombined” and the coefficients were re-estimated). Accompanying these coefficients is the odds ratio for each risk factor. For a binary variable, this ratio is the change in the odds for a patient with the risk factor compared to a patient without it. Using the outcome of wound infection for an obese patient as an example, the odds ratio is the probability of acquiring a wound infection if the patient was obese versus the probability of wound infection if the patient was not obese. Odds ratios are not applicable for continuous variables (e.g., age, age-squared, and MQPredLOS).

Calculation of Expected Values

Once the risk factors were identified for each cohort, separate models were run. These models estimated the relative effects (β_n) that the risk factors had on the relevant outcome value for each patient, and generated model equations of the form:

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

where:

- β_n = the relevant model coefficient (β_0 is the intercept)
- X_n = the value of the risk factor for a patient

These models were then used to provide the predicted values for each individual patient's outcomes (after exclusions). The risk factor values (x) were multiplied by the model coefficients (β) and summed to determine the value βX for each patient. For linear models (e.g., post-operative length of stay), this value βX was the final predicted value. See Example 1 in Appendix C: Calculating the Risk-Adjusted Post-Operative Length of Stay Using Linear Regression.

For logistic models (e.g., deep joint infection or device problem, blood clot lung/leg, wound infection, and readmission), the predicted values were calculated as:

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

where $e \approx 2.7182818285$

The expected number for an individual hospital/surgeon is the sum of these predicted values for all patients at that hospital or for that particular surgeon. See Example 2a in Appendix C.

Determining Statistical Ratings

Significance tests using Z scores were performed for deep joint infection or device problem, blood clot lung/leg, wound infection, and readmission. Even though the observed value for any single hospital or surgeon may be comparable to its expected value, random variation plays a role in such a comparison. Therefore, statistical evaluation was used to determine whether or not the difference between the observed and the expected value was *too large* to be attributed solely to chance.

Calculation of Z Scores

The Z score was calculated by determining the difference between actual and expected values, then dividing that number by the standard deviation. The first step in determining a hospital's or surgeon's Z score for a particular measure was to calculate the estimated variance for each patient. The sum of the estimated variance for each patient was used to calculate the standard deviation, which was then used to determine a particular hospital's/surgeon's Z score (see formulas below).

Step 1: Compute the estimated variance of each patient's probability of an occurring event

$$\text{Estimated Variance} = P(1 - P)$$

where: P = the predicted value of the event for a patient

Step 2: Calculate the Standard Deviation of the occurring event

SUMVAR = sum of estimated variance across all patients
Standard Deviation of an event = the square root of SUMVAR

$$\text{Z score} = \frac{\text{Actual number of events} - \text{Expected number of events}}{\text{Standard Deviation of the events}}$$

Determination of p Values

A Z score table was used to determine p values. On the table each calculated Z score has a corresponding p value. The rating process evaluated both fewer than expected as well as greater than expected events. Thus a two-tailed test was used. The two-tailed p value was determined for each hospital and surgeon analyzed.

Assignment of Statistical Rating

Both the p value, determined in terms of a "two-tailed" test, and the Z score were used to determine the statistical rating. For example, in determining the readmission rating for a hospital:

- if the calculated p value was greater than or equal to 0.05, then the conclusion was made that the difference between what was expected and what was observed was *not* statistically significant.
- 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 Z score was less than 0, then the observed number of readmissions was less than the expected number of readmissions and the hospital was assigned the symbol "○" (as shown in the *Total Hip and Knee Replacements* report) to indicate that the number of readmissions was significantly less than expected.
 - If the Z score was greater than 0, then the observed number of readmissions was higher than the expected number of readmissions and the hospital was assigned the symbol "●" (as shown in *Total Hip and Knee Replacements* report) to indicate that the number of readmissions was significantly greater than expected.

Calculation of Expected Range

Lower limit = Expected Deaths – 1.960 (Standard Deviation of the events)

Upper limit = Expected Deaths + 1.960 (Standard Deviation of the events)

See Example 2b in Appendix C

Methodology for Analysis of Average Hospital Charge

Average hospital charge was reported for hospitals only. For knee replacements the average charge was trimmed and case-mix adjusted. For total hip replacements the average charge was trimmed; however, there was insufficient volume for case-mix adjustment by DRGs. The patients included in the charge analysis represent two different DRGs:

- DRG 209: Major Joint And Limb Reattachment Procedures of Lower Extremity, and
- DRG 471: Bilateral Or Multiple Major Joint Procedures of Lower Extremity.

Trimming

Trimming methodology was used to remove outlier cases from the average charge analyses. Exclusion of outliers was imperative for the elimination of extreme values that otherwise would have had a significant and unrepresentative impact on the mean (average). For the *Total Hip and Knee Replacements* report, the mean was the primary descriptive measure for average charge. The trimming (that is, deleting) of individual records from the database was performed after all exclusions were satisfied.

Trim points for average charge were calculated using the “+/- 3.0 interquartile range” method (IQR). This non-parametric methodology was used because historically the distribution for charge data does not follow a “normal, bell-shaped” pattern.

Since charges for the same DRG vary dramatically among geographic regions within Pennsylvania, trim points were calculated at the regional level. PHC4 uses nine regional designations. For knee replacements trim points were calculated at the regional level for two groups, patients assigned to DRG 209 and those assigned to DRG 471. However, due to the insufficient volume of patients assigned to DRG471 for total hip replacements, trim points for total hip replacements were calculated at the regional level for a single group including patients assigned to DRG 290 or DRG 471. Therefore, 18 sets of upper and lower trim points were used for knee replacements and nine sets were used for total hip replacements.

Trim points for average charge were determined as follows:

Q1 = the first quartile (25th percentile charge value)

Q3 = the third quartile (75th percentile charge value)

IQR = Q3 – Q1

Lower Trim Point = Q1 – (3.0 x IQR)

Upper Trim Point = Q3 + (3.0 x IQR)

Charges of less than \$5,000 were considered invalid and excluded from the analysis. Therefore, the lower trim points, which were all less than \$5,000, were not used in the analyses. See Data Tables 7A and 7B for upper trim points, median charge and the percent of outliers for each region for total hip replacements and for each DRG and region for knee replacements.

Case-Mix Adjustment (Calculated for knee replacements only)

Hospital charges for knee replacements were trimmed (as described above) and then adjusted by case mix. Using case-mix adjustment, a composite average charge was developed for each of the two groups of patients, those assigned to DRG 209 and those assigned to DRG 471, for each of the nine regions. The charges associated with each group were adjusted according to the number of patients and the relative cost associated with treating patients in each of the two groups.

First, regional relative weights for each of the two groups were determined. After all exclusions were satisfied and outlier trimming was performed, the relative weight for each of the two groups within each of the nine regions was calculated using the formula:

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

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

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

where, for a hospital located in a particular region:

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

n_i = the number of cases (corresponding to each of the two groups), and

$\sum n_i$ = the total number of cases for the hospital (sum of the two groups)

Calculation of Average Charge

For total hip replacements, the trimmed average charge for each hospital was calculated as:

$$\text{Trimmed Average Charge} = \frac{\text{Total Charges for the Hospital}}{\text{Total Number of Cases for the Hospital}}$$

For knee replacements, the trimmed and case-mix adjusted average charge for each hospital was calculated as:

$$\text{Trimmed and Case-Mix Adjusted Charge} = \frac{\text{Trimmed Average Charge}}{\text{Case-Mix Index}}$$

See Data Table 8 for average charges and relative weights associated with each DRG group for each region. Example 3 in Appendix C demonstrates the calculation of average hospital charge for knee replacements.

DATA TABLES

**Table 1. Summary of Statewide Results
Total Hip and Knee Replacements**

Total Hip and Knee Replacements	29,710	100.0%
<i>Total Hip Replacements</i>	9,769	32.9%
<i>Knee Replacements</i>	19,941	67.1%
Total Complications Identified		
<i>Deep Joint Infection or Device Problem</i>	706	2.4%
<i>Blood Clot Lung/Leg</i>	380	1.3%
<i>Wound Infection</i>	147	0.5%
Total Readmissions Identified	1,307	4.4%
Post-Operative Length of Stay	3.7 days	
Average Hospital Charge		
<i>Total Hip Replacements</i>	\$27,759	
<i>Knee Replacements</i>	\$26,015	

Table 2. Statewide Exclusion Data for Total Hip and Knee Replacements Analysis

Exclusion Criteria	#	%
Total verified cases before exclusions	30,854	100.0
Standard exclusions:		
Unverified cases ¹	133	0.4
< 18 years of age	10	< 0.1
Clinically complex cases ²	929	3.0
Cases with invalid/inconsistent data for linkages	20	< 0.1
Patients who left hospital against medical advice	7	< 0.1
Patients who died during the hospitalization in which the total hip or knee replacement was performed.	45	0.2
Total standard exclusions	1,144	3.7
Total cases to be included in the analysis	29,710	96.3
Exclusions Specific to Post-Operative Length of Stay		
Standard exclusions	1,144	3.7
Tracheostomy (DRG 483)	7	< 0.1
Post-operative LOS < 1 day or > 21 days	28	< 0.1
Total exclusions from post-op length of stay analysis	1,179	3.8
Total cases to be included in the post-op length of stay analysis	29,675	96.2
Exclusions Specific to Average Hospital Charge		
Standard exclusions	1,144	3.7
Tracheostomy (DRG 483)	7	< 0.1
Invalid charge (e.g., < \$5,000)	18	< 0.1
Charge outliers	528	1.7
Total exclusions from average charge analysis	1,697	5.5
Total cases to be included in the average charge analysis	29,157	94.5

¹Cases from hospitals that closed after the initial verification process and prior to PHC4's request to hospitals and surgeons for additional data (see *Hospital and Orthopedic Surgeon Verification of Data*).

²Clinically complex cases included any of the following:

- The discharge record was not assigned to one of the following DRGs:
 - DRG 209: Major Joint And Limb Reattachment Procedures of Lower Extremity
 - DRG 471: Bilateral Or Multiple Major Joint Procedures of Lower Extremity
 - DRG 483: Tracheostomy Except for Face, Mouth and Neck Diagnoses.
- Revisions: For total hip replacements, a hip revision procedure (81.53) was the principal procedure, performed on the same day, or performed prior to the total hip replacement. For knee replacements, a knee revision procedure (81.55) was the principal procedure, performed on the same day, or performed prior to the knee replacement.
- A partial hip replacement procedure (81.52) was performed anytime during the same hospitalization.
- Total hip and knee replacements were performed during the same hospitalization.
- Any one of the following diagnoses was present:
 - Complication from a prior orthopedic surgery: Principal diagnosis of 996.4, 996.77, or 996.78
 - Bone cancer: Principal or secondary diagnosis of 170.0, 170.1, 170.2, 170.3, 170.4, 170.5, 170.6, 170.7, 170.8, 170.9, or 198.5.
 - Fracture of hip/knee: Principal diagnosis for hip: 733.14, 733.15, 733.81, 733.82, 808.0, 808.1, 820.00, 820.01, 820.02, 820.03, 820.09, 820.10, 820.11, 820.12, 820.13, 820.19, 820.20, 820.21, 820.22, 820.30, 820.31, 820.32, 820.8, 820.9, 821.00, 821.01, 821.10, or 821.11; principal diagnosis for knee: 733.16, 733.81, 733.82, 821.20, 821.21, 821.22, 821.23, 821.29, 821.30, 821.31, 821.32, 821.33, 821.39, 822.0, 822.1, 823.00, 823.01, 823.02, 823.10, 823.11, 823.12, 823.20, 823.21, 823.22, 823.30, 823.31, 823.32, 823.80, 823.81, 823.82, 823.90, 823.91, or 823.92
 - Joint infection of hip/knee: Principal diagnosis for hip: 730.05, 730.15, 730.25, 730.35, 730.95, 711.05, 711.95, 996.66, or 96.67; principal diagnosis for knee: 730.06, 730.16, 730.26, 730.36, 730.96, 711.06, 711.96, 996.66, or 996.67.
- Special requests

**Table 4. p Values for Significant Predictors in the Development Sample
Total Hip and Knee Replacements**

<i>Significant Predictor</i>	<i>p Value</i>	<i>Significant Predictor</i>	<i>p Value</i>
Deep Joint Infection or Device Problem		Post-Operative Length of Stay	
Age/Sex/Hip/Knee Category	<0.001	Age-Squared	<0.0001
<i>Atlas Outcomes™</i> Predicted Length of Stay	0.022	Alzheimer's and/or Parkinson's	0.0005
Coagulation Defects	0.020	Anemia	<0.0001
Heart Failure	0.079	<i>Atlas Outcomes™</i> Predicted Length of Stay	<0.0001
Medical Assistance	<0.001	Bilateral or multiple joint procedures of the hip or leg	<0.0001
Blood Clot Lung/Leg		Cancer	0.0378
Age	0.049	Chronic Obstructive Pulmonary Disease	<0.0001
<i>Atlas Outcomes™</i> Predicted Length of Stay*	0.045	Coagulation Defects	<0.0001
Bilateral or multiple joint procedures of the hip or leg*	0.071	Coronary Atherosclerosis	0.0009
Bone Quality – Poor*	0.011	Depression, Psychoses, and Dementia	0.0002
Coagulation Defects	0.013	Diabetes with Complications	0.0083
Heart Valve Diseases	0.066	Discharge Status Category	<0.0001
Total Hip Replacement	0.086	Heart Failure	<0.0001
Wound Infection		Heart Valve Diseases	0.0008
<i>Atlas Outcomes™</i> Predicted Length of Stay	0.057	Hypertensions with Complications	0.0007
Chronic Obstructive Pulmonary Disease	0.096	Medical Assistance	<0.0001
Medical Assistance	0.001	Obesity – Morbid	<0.0001
Obesity	0.027	Race Category	0.0002
Readmission		Total Hip Replacement	<0.0001
Age/Sex Category	<0.001		
<i>Atlas Outcomes™</i> Predicted Length of Stay	0.006		
Chronic Obstructive Pulmonary Disease	0.001		
Coronary Atherosclerosis	0.049		
Gait Abnormality	0.021		
History of Pacemaker	0.010		
Hypertensions with Complications	0.082		
Medical Assistance	0.001		
Pennsylvania Resident	0.057		
Tobacco Use Disorder	0.050		

*This risk factor did not cross-validate; therefore, it was not included in the final risk model.

**Table 5. Coefficients and Odds Ratios for Risk Factors in the Final Models
Total Hip and Knee Replacements**

Risk Factor	Coefficient	Odds Ratio
Deep Joint Infection or Device Problem		
Constant	-5.2160	
Age/Sex/Hip/Knee Category:		
<i>Female < 65, total hip replacement</i>	1.0079	2.740
<i>Female ≥ 65 to < 75, total hip replacement</i>	0.4597	1.584
<i>Female ≥ 75, total hip replacement</i>	0.8392	2.315
<i>Male < 65, total hip replacement</i>	0.5694	1.767
<i>Male ≥ 65 to < 75, total hip replacement</i>	0.6494	1.914
<i>Male ≥ 75, total hip replacement</i>	1.0654	2.902
<i>Female < 65, knee replacement</i>	0.5569	1.745
<i>Female ≥ 65, knee replacement</i>	*	*
<i>Male < 75, knee replacement</i>	0.7548	2.127
<i>Male ≥ 75, knee replacement</i>	-0.0197	0.980
<i>Atlas Outcomes™</i> Predicted Length of Stay	0.2476	NA
Coagulation Defects	0.8796	2.410
Heart Failure	0.4793	1.615
Medical Assistance	0.8267	2.286
Blood Clot Lung/Leg		
Constant	-5.1667	
Age	0.0126	NA
Coagulation Defects	1.2905	3.635
Heart Valve Diseases	0.4130	1.511
Total Hip Replacement	-0.2635	0.768
Wound Infection		
Constant	-7.7885	
<i>Atlas Outcomes™</i> Predicted Length of Stay	0.6182	NA
Chronic Obstructive Pulmonary Disease	0.4660	1.594
Medical Assistance	1.0553	2.873
Obesity	0.6494	1.914
Readmission		
Constant	-5.4865	
Age/Sex Category:		
<i>Female < 65</i>	0.0638	1.066
<i>Female ≥ 65 to < 75</i>	0.0937	1.098
<i>Female ≥ 75</i>	0.2606	1.298
<i>Male < 65</i>	*	*
<i>Male ≥ 65 to < 75</i>	0.1389	1.149
<i>Male ≥ 75</i>	0.5376	1.712
<i>Atlas Outcomes™</i> Predicted Length of Stay	0.4602	NA
Chronic Obstructive Pulmonary Disease	0.4859	1.626
Coronary Atherosclerosis	0.2825	1.326
Gait Abnormality	0.5542	1.741
History of Pacemaker	0.5435	1.722
Hypertensions with Complications	0.6130	1.846
Medical Assistance	0.7903	2.204
Pennsylvania Resident	0.3888	1.475
Tobacco Use Disorder	0.3531	1.424

*This is the reference level for the variable.

NA: Odds ratios are not applicable to continuous variables such as age in years and *Atlas Outcomes™* Predicted Length of Stay. The odds ratio can be calculated when age is modeled as a categorical variable.

Table 5. Coefficients and Odds Ratios for Risk Factors in the Final Models *continued*
Total Hip and Knee Replacements

Risk Factor	Coefficient
<i>Post-Operative Length of Stay</i>	
Constant	7.265738400
Age-Squared	0.000061295
Alzheimer's and/or Parkinson's	0.440227686
Anemia	0.267458334
<i>Atlas Outcomes™</i> Predicted Length of Stay	0.412840222
Bilateral or multiple joint procedures of the hip or leg	0.795216465
Cancer	0.174676080
Chronic Obstructive Pulmonary Disease	0.315794092
Coagulation Defects	0.806098699
Coronary Atherosclerosis	0.106638784
Depression, Psychoses, and Dementia	0.196177552
Diabetes with Complications	0.236834123
Discharge Status Category	
<i>Rehabilitation unit/facility</i>	-0.190721710
<i>Skilled nursing facility</i>	0.303329966
<i>Home</i>	0.399901902
<i>Other</i>	*
Heart Failure	0.691531557
Heart Valve Diseases	0.259086419
Hypertensions with Complications	0.583415091
Medical Assistance	0.369677144
Obesity – Morbid	0.284854646
Race Category	
<i>Black</i>	0.273618844
<i>Other</i>	0.084438164
<i>White</i>	*
Total Hip Replacement	0.179298569

*This is the reference level for the variable.

Note: Odds ratios are not applicable to linear regression models (i.e., the post-operative length of stay model).

**Table 6. Statewide Frequencies for Candidate Variables
Total Hip and Knee Replacements**

Risk Factor	Statewide Cases		Deep Joint Infection or Device Problem		Blood Clot Lung/Leg		Wound Infection		Readmission		Post-Operative Length of Stay		
	N	%	N	%	N	%	N	%	N	%	N	%	Days
c Statistic			0.613		0.561		0.607		0.618				
R-square											7.3%		
Total Cases	29,710	100.0	706	2.4	380	1.3	147	0.5	1,307	4.4	29,675	100.0	3.7
Age and Age-Squared <i>Tested as continuous variables</i>													
			na		Age = ✓ Age-squared=ns		Age = ns Age-squared=ns		na		Age = ns Age-squared = ✓		
18 to 29 years	60	0.2			0	0.0	0	0.0			60	0.2	3.7
30 to 39 years	378	1.3			3	0.8	2	0.5			378	1.3	3.7
40 to 49 years	1,934	6.5			21	1.1	12	0.6			1,933	6.5	3.5
50 to 59 years	5,112	17.2			60	1.2	31	0.6			5,105	17.2	3.6
60 to 69 years	8,260	27.8			88	1.1	44	0.5			8,253	27.8	3.6
70 to 79 years	10,386	35.0			154	1.5	44	0.4			10,374	35.0	3.7
80 to 89 years	3,477	11.7			52	1.5	14	0.4			3,470	11.7	3.9
90 to 99 years	103	0.3			2	1.9	0	0.0			102	0.3	4.8
Average Age: 67.0 years; Female; 67.7 years; Male 65.7 years													
Age/Sex Category													
			na		na		na		✓		na		
Female < 65	6,470	21.8							241	3.7			
Female ≥ 65 to < 75	6,374	21.5							252	4.0			
Female ≥ 75	5,600	18.8							287	5.1			
Male < 65	4,574	15.4							156	3.4			
Male ≥ 65 to < 75	3,830	12.9							168	4.4			
Male ≥ 75	2,862	9.6							203	7.1			
Age/Sex/Hip/Knee Category													
			✓		na		na		na		na		
Female < 65, total hip replacement	1,819	6.1	70	3.8									
Female ≥ 65 to < 75, total hip replmnt	1,830	6.2	40	2.2									
Female ≥ 75, total hip replacement	1,861	6.3	63	3.4									
Male < 65, total hip replacement	2,102	7.1	51	2.4									
Male ≥ 65 to < 75, total hip replmnt	1,207	4.1	32	2.7									
Male ≥ 75, total hip replacement	950	3.2	40	4.2									
Female < 65, knee replacement	4,651	15.7	116	2.5									
Female ≥ 65, knee replacement	8,283	27.9	118	1.4									
Male < 75, knee replacement	5,095	17.1	148	2.9									
Male ≥ 75, knee replacement	1,912	6.4	28	1.5									
Alzheimer's and/or Parkinson's													
			na		na		na		na		✓		
No	29,440	99.1									29,407	99.1	3.7
Yes	270	0.9									268	0.9	4.2
Anemia													
			na		na		na		na		✓		
No	29,018	97.7									28,986	97.7	3.7
Yes	692	2.3									689	2.3	4.1
Atlas Outcomes™ Predicted Length of Stay <i>Tested as a continuous variable</i>													
			✓		✓*		✓		✓		✓		
≤ 3.431 days	5,873	19.8	136	2.3	72	1.2	22	0.4	200	3.4	5,870	19.8	3.4
3.432 to 3.591 days	6,003	20.2	144	2.4	66	1.1	26	0.4	212	3.5	5,998	20.2	3.6
3.592 to 3.726 days	5,940	20.0	130	2.2	95	1.6	26	0.4	222	3.7	5,936	20.0	3.6
3.727 to 3.939 days	5,932	20.0	121	2.0	80	1.3	31	0.5	269	4.5	5,925	20.0	3.7
≥ 3.940 days	5,962	20.1	175	2.9	67	1.1	42	0.7	404	6.8	5,946	20.0	4.0
Bilateral or multiple joint procedures of the hip or leg													
			na		✓*		na		na		✓		
No	27,761	93.4			349	1.3					27,733	93.5	3.6
Yes	1,949	6.6			31	1.6					1,942	6.5	4.2

✓: significant—used in the final model as a risk-adjustment factor
 ns: not significant—not included in the final model
 na: variable not applicable to this particular model
 *This risk factor did not cross-validate; therefore, it was not included in the final risk model.

**Table 6. Statewide Frequencies for Candidate Variables *continued*
Total Hip and Knee Replacements**

Risk Factor	Statewide Cases		Deep Joint Infection or Device Problem		Blood Clot Lung/Leg		Wound Infection		Readmission		Post-Operative Length of Stay		
	N	%	N	%	N	%	N	%	N	%	N	%	Days
Bone Quality – Poor													
No	28,146	94.7	na		350	1.2	na		na		na		
Yes	1,564	5.3			30	1.9							
Cancer													
No	29,367	98.8	na		373	1.3	na		na		29,332	98.8	3.7
Yes	343	1.2			7	2.0					343	1.2	4.0
Cardiomyopathy													
No	29,510	99.3	na		na		145	0.5	1,291	4.4	29,475	99.3	3.7
Yes	200	0.7					2	1.0	16	8.0	200	0.7	4.1
Chronic Obstructive Pulmonary Disease													
No	28,022	94.3	ns		na		132	0.5	1,167	4.2	27,993	94.3	3.7
Yes	1,688	5.7					15	0.9	140	8.3	1,682	5.7	4.1
Chronic Renal Failure													
No	29,672	99.9	na		na		na		1,302	4.4	na		
Yes	38	0.1							5	13.2			
Coagulation Defects													
No	29,442	99.1	✓		368	1.2	144	0.5	1,291	4.4	29,412	99.1	3.7
Yes	268	0.9			12	4.5	3	1.1	16	6.0	263	0.9	4.6
Coronary Atherosclerosis													
No	25,635	86.3	ns		na		na		1,044	4.1	25,608	86.3	3.7
Yes	4,075	13.7			116	2.8			263	6.5	4,067	13.7	3.9
Depression, Psychoses, and Dementia													
No	27,509	92.6	ns		na		na		na		27,476	92.6	3.7
Yes	2,201	7.4			74	3.4					2,199	7.4	3.8
Diabetes Category													
None	25,185	84.8	ns		na		na		na		na		
Without complications	4,197	14.1			121	2.9							
With complications	328	1.1			14	4.3							
Diabetes with Complications													
No	29,382	98.9	na		na		na		1,283	4.4	29,349	98.9	3.7
Yes	328	1.1							24	7.3	326	1.1	4.1
Discharge Category													
Rehabilitation unit/facility	14,049	47.3	na		na		na		na		14,044	47.3	3.5
Skilled nursing facility	4,105	13.8									4,094	13.8	4.0
Home	8,338	28.1									8,328	28.1	3.9
Other	3,218	10.8									3,209	10.8	3.7
Gait Abnormality													
No	29,504	99.3	na		na		na		1,291	4.4	na		
Yes	206	0.7							16	7.8			

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 *This risk factor did not cross-validate; therefore, it was not included in the final risk model.

Table 6. Statewide Frequencies for Candidate Variables *continued*
Total Hip and Knee Replacements

Risk Factor	Statewide Cases		Deep Joint Infection or Device Problem		Blood Clot Lung/Leg		Wound Infection		Readmission		Post-Operative Length of Stay		
	N	%	N	%	N	%	N	%	N	%	N	%	Days
Heart Failure			✓		ns		na		ns		✓		
No	28,993	97.6	678	2.3	368	1.3			1,235	4.3	28,963	97.6	3.7
Yes	717	2.4	28	3.9	12	1.7			72	10.0	712	2.4	4.7
Heart Valve Diseases			na		✓		ns		ns		✓		
No	28,444	95.7			355	1.2	139	0.5	1,233	4.3	28,412	95.7	3.7
Yes	1,266	4.3			25	2.0	8	0.6	74	5.8	1,263	4.3	4.1
History of Myocardial Infarction			na		na		na		ns		na		
No	28,479	95.9							1,225	4.3			
Yes	1,231	4.1							82	6.7			
History of Pacemaker			ns		na		na		✓		ns		
No	29,317	98.7	693	2.4					1,268	4.3	29,283	98.7	3.7
Yes	393	1.3	13	3.3					39	9.9	392	1.3	4.0
History of Thrombosis			na		ns		na		ns		ns		
No	28,992	97.6			365	1.3			1,257	4.3	28,957	97.6	3.7
Yes	718	2.4			15	2.1			50	7.0	718	2.4	3.8
Hypertension with Complications			na		na		na		✓		✓		
No	29,548	99.5							1,289	4.4	29,514	99.5	3.7
Yes	162	0.5							18	11.1	161	0.5	4.7
Late Effects of Stroke			na		na		ns		na		na		
No	29,599	99.6					145	0.5					
Yes	111	0.4					2	1.8					
Medical Assistance			✓		na		✓		✓		✓		
No	28,957	97.5	663	2.3			137	0.5	1,249	4.3	8,923	97.5	3.7
Yes	753	2.5	43	5.7			10	1.3	58	7.7	752	2.5	4.0
Obesity			na		na		✓		na		na		
No	26,904	90.6					123	0.5					
Yes	2,806	9.4					24	0.9					
Obesity/Hip/Knee Category			ns		na		na		na		na		
None, total hip replacement	9,078	30.6	271	3.0									
Unspecified, total hip replacement	525	1.8	15	2.9									
Morbid, total hip replacement	166	0.6	10	6.0									
None, knee replacement	17,826	60.0	360	2.0									
Unspecified, knee replacement	1,637	5.5	33	2.0									
Morbid, knee replacement	478	1.6	17	3.6									
Obesity – Morbid			na		na		na		na		✓		
No	29,066	97.8									29,033	97.8	3.7
Yes	644	2.2									642	2.2	3.9
Pennsylvania Resident			ns		ns		ns		✓		ns		
No	2,296	7.7	49	2.1	24	1.0	6	0.3	68	3.0	2,291	7.7	3.8
Yes	27,414	92.3	657	2.4	356	1.3	141	0.5	1,239	4.5	27,384	92.3	3.7

✓: significant—used in the final model as a risk-adjustment factor
 ns: not significant—not included in the final model
 na: variable not applicable to this particular model

**Table 6. Statewide Frequencies for Candidate Variables *continued*
Total Hip and Knee Replacements**

Risk Factor	Statewide Cases		Deep Joint Infection or Device Problem		Blood Clot Lung/Leg		Wound Infection		Readmission		Post-Operative Length of Stay		
	N	%	N	%	N	%	N	%	N	%	N	%	Days
Peripheral Vascular Disease													
			ns		na		na		ns		ns		
No	29,311	98.7	692	2.4					1,279	4.4	29,277	98.7	3.7
Yes	399	1.3	14	3.5					28	7.0	398	1.3	4.0
Race Category													
			na		ns		na		ns		✓		
Black	1,380	4.6			13	0.9			73	5.3	1,378	4.6	3.9
Other	2,894	9.7			28	1.0			96	3.3	2,889	9.7	3.8
White	25,436	85.6			339	1.3			1,138	4.5	25,408	85.6	3.7
Tobacco Use Disorder													
			ns		na		na		✓		na		
No	28,573	96.2	659	2.3					1,240	4.3			
Yes	1,137	3.8	47	4.1					67	5.9			
Total Hip Replacement													
			ns		✓		ns		ns		✓		
No	19,941	67.1	410	2.1	277	1.4	104	0.5	852	4.3	19,918	67.1	3.6
Yes	9,769	32.9	296	3.0	103	1.1	43	0.4	455	4.7	9,757	32.9	3.8
Underlying Disease Category													
			ns		na		na		na		na		
Total hip replacement with principal diagnosis of arthropathy, aseptic necrosis, and/or rheumatoid arthritis	854	2.9	39	4.6									
Total hip replacement with principal diagnosis of osteoarthritis and/or other	8,915	30.0	257	2.9									
Knee replacement with principal diagnosis of arthropathy, aseptic necrosis, and/or other	283	1.0	11	3.9									
Knee replacement with principal diagnosis of osteoarthritis and/or rheumatoid arthritis	19,658	66.2	399	2.0									

✓: significant—used in the final model as a risk-adjustment factor
 ns: not significant—not included in the final model
 na: variable not applicable to this particular model

**Table 7A. Trim Points and Median Charge
Total Hip Replacements**

	<u>Upper Trim Point*</u>	<u>Median Charge</u>	<u>Outlier %</u>
DRGs 209 and 471			
Region 1	\$60,056	\$22,274	1.5
Region 2	\$54,297	\$20,924	0.9
Region 3	\$47,195	\$22,131	0.9
Region 4	\$32,195	\$18,243	2.6
Region 5	\$39,941	\$18,502	2.0
Region 6	\$56,866	\$19,566	0.5
Region 7	\$51,721	\$19,664	0.2
Region 8	\$116,119	\$33,614	0.6
Region 9	\$87,922	\$39,311	5.4

*Charges of less than \$5,000 were considered invalid so no lower trim point is displayed.

**Table 7B. Trim Points and Median Charge
Knee Replacements**

	<u>Upper Trim Point*</u>	<u>Median Charge</u>	<u>Outlier %</u>
DRG 209			
Region 1	\$47,520	\$19,660	1.9
Region 2	\$47,248	\$18,912	0.2
Region 3	\$44,482	\$20,622	1.2
Region 4	\$30,437	\$17,093	1.7
Region 5	\$39,669	\$17,235	1.7
Region 6	\$50,731	\$19,343	0.5
Region 7	\$45,797	\$17,264	0.4
Region 8	\$90,399	\$30,877	0.9
Region 9	\$107,119	\$38,956	4.2
DRG 471			
Region 1	\$66,992	\$28,091	0.7
Region 2	\$60,322	\$26,483	0.0
Region 3	\$69,315	\$30,275	3.4
Region 4	\$45,811	\$24,927	0.0
Region 5	\$71,819	\$24,720	0.0
Region 6	\$93,054	\$25,121	0.0
Region 7	\$69,501	\$25,659	0.0
Region 8	\$160,457	\$61,021	0.0
Region 9	\$103,189	\$52,335	7.9

*Charges of less than \$5,000 were considered invalid so no lower trim point is displayed.

**Table 8. Average Hospital Charge and Related Relative Weights
Knee Replacements**

	<u>Average Hospital Charge</u>	<u>Relative Weight</u>
DRG 209		
Region 1	\$21,205	0.98523314
Region 2	\$19,788	0.96877640
Region 3	\$20,965	0.95767676
Region 4	\$16,754	0.94444754
Region 5	\$18,865	0.98058928
Region 6	\$20,002	0.95663427
Region 7	\$17,637	0.97514003
Region 8	\$34,347	0.93348248
Region 9	\$43,965	0.94420851
DRG 471		
Region 1	\$31,774	1.47628486
Region 2	\$27,510	1.34679009
Region 3	\$33,560	1.53298587
Region 4	\$24,556	1.38426733
Region 5	\$27,637	1.43657392
Region 6	\$29,976	1.43365732
Region 7	\$26,337	1.45618048
Region 8	\$64,141	1.74320533
Region 9	\$54,893	1.17890583

**Table 9. Statewide Readmission Data, by Reason for Readmission
Total Hip and Knee Replacements**

<i>Diagnosis</i>	<i>ICD.9.CM Code</i>	<i># of Readmits</i>	<i>% of All Cases</i>
All Readmissions		1,307	4.4%
Circulatory Diagnoses			
<u>Cardiac dysrhythmias</u>		49	3.7
Conduction disorders (i.e., av block)	426.0, 426.12	2	0.2
Paroxysmal tachycardias.....	427.0, 427.1	4	0.3
Atrial fibrillation/flutter	427.31, 427.32	31	2.4
Miscellaneous dysrhythmias.....	427.81	1	0.1
Other rhythm disorders (i.e., ectopic, nodal).....	427.89	7	0.5
Tachycardia, unspecified.....	785.0	1	0.1
Palpitations.....	785.1	2	0.2
Abnormal electrocardiogram	794.31	1	0.1
<u>Heart failure/hypertensive heart disease/hypertension/ hypotension</u>		36	2.8
Unspecified hypertensive heart disease with CHF	402.91	2	0.2
Pericardial disease	423.9	1	0.1
Congestive heart failure.....	428.0	33	2.5
<u>Coronary atherosclerosis/myocardial ischemia and infarction</u>		45	3.4
Hypertension	401.9, 403.91	2	0.2
Acute myocardial infarction	410.11, 410.31, 410.41, 410.71, 418.81	13	1.0
Angina	411.1, 413.9	2	0.2
Coronary atherosclerosis.....	414.00, 414.01	23	1.8
Hypotension	458.0, 458.9	5	0.4
<u>Artery and vein disease/embolism/thrombosis</u>		123	9.4
Pulmonary embolism & infarction ¹	415.11, 415.19	36	2.8
Thoracic aorta dissection.....	441.01	1	0.1
Peripheral vascular disease, unspecified	443.9	2	0.2
Arterial embolism and thrombosis	444.22	2	0.2
Phlebitis and thrombophlebitis ¹	451.0, 451.11, 451.19, 451.2	12	0.9
Other venous embolism and thrombosis ¹	453.8, 453.9	26	2.0
Edema	782.3	3	0.2
Peripheral vascular complications (thrombophlebitis) resulting from procedure ¹ ..	997.2	37	2.8
Vascular complications of other vessels.....	997.79 ²	3	0.2
Other vascular complications (following infusion, perfusion or transfusion).....	999.2	1	0.1
<u>Anemia/thrombocytopenia</u>		13	1.0
Iron deficiency anemias.....	280.0, 280.9	2	0.2
Other and unspecified anemias (i.e. post hemorrhagic anemia)	285.1, 285.8	3	0.2

¹These conditions were also defined as complications.

²New code effective Q-4, 2001.

**Table 9. Statewide Readmission Data, by Reason for Readmission *continued*
Total Hip and Knee Replacements**

<i>Diagnosis</i>	<i>ICD.9.CM Code</i>	<i># of Readmits</i>	<i>% of all Readmits</i>
<u>Anemia/thrombocytopenia <i>continued</i></u>			
Coagulation defects	286.7, 286.9	4	0.3
Hemorrhage, unspecified (i.e. rupture of blood vessel)	459.0	1	0.1
Hemoperitoneum non-traumatic	568.81	1	0.1
Abnormal coagulation profile.....	790.92	2	0.2
Respiratory Diagnoses			
<u>Pleurisy</u>		4	0.3
Pleurisy	511.0	1	0.1
Pleural effusion/atelectasis	511.9	1	0.1
Alveolar pneumonopathy	516.8	1	0.1
Pulmonary collapse.....	518.0	1	0.1
<u>Pulmonary edema/insufficiency</u>		5	0.4
Acute respiratory failure	518.81	5	0.4
<u>Respiratory and other chest symptoms</u>		60	4.6
Bronchitis, asthma, airway obstruction....	491.20, 491.21, 493.02, 493.21, 493.92, 496	20	1.5
Respiratory and other chest symptoms (i.e., shortness of breath, chest pain)	786.05, 786.09, 786.50, 786.52, 786.59	39	3.0
Abnormal pulmonary function study.....	794.2	1	0.1
<u>Aspiration pneumonia</u>	507.0	6	0.5
Gastrointestinal Diagnoses			
<u>GI hemorrhage/complications</u>		65	5.0
Acute gastric ulcer with hemorrhage.....	531.00	2	0.2
Chronic gastric ulcer with hemorrhage.....	531.40	5	0.4
Gastric ulcer, unspecified.....	531.90	1	0.1
Acute duodenal ulcer	532.00	2	0.2
Chronic unspecified duodenal ulcer	532.40, 532.50	6	0.5
Chronic unspecified peptic ulcer	533.90	2	0.2
Gastritis.....	535.40, 535.41, 535.50	9	0.7
Stomach function disorders.....	536.2, 536.8, 537.83	3	0.2
Blood in stool	578.1	7	0.5
Hemorrhage of gastrointestinal tract, unspecified	578.9	11	0.8
Anorexia.....	783.0	1	0.1
Symptoms of digestive system.....	787.01, 787.02, 787.91	8	0.6
Abdominal pain	789.00, 789.06	5	0.4
Closed rectal injury	863.45	1	0.1
Digestive system complications due to procedure	997.4	2	0.2

**Table 9. Statewide Readmission Data, by Reason for Readmission *continued*
Total Hip and Knee Replacements**

<i>Diagnosis</i>	<i>ICD.9.CM Code</i>	<i># of Readmits</i>	<i>% of all Readmits</i>
<u>Diseases of the digestive system</u>		85	6.5
Ulcer, stricture, reflux of esophagus.....	530.10, 530.2, 530.3, 530.81	9	0.7
Acute appendicitis.....	540.0, 540.9	2	0.2
Inguinal hernia.....	550.10	1	0.1
Other hernia.....	552.1, 552.21	4	0.3
Regional enteritis; large intestine.....	555.1	1	0.1
Acute vascular insufficiency, intestine.....	557.0, 557.9	2	0.2
Gastroenteritis.....	558.9	8	0.6
Intestinal obstruction.....	560.1, 560.9	10	0.8
Diverticulitis.....	562.10, 562.11, 562.12, 562.13	14	1.1
Functional disorders (constipation, irritable bowel).....	564.0, 564.09, 564.1, 564.89	6	0.5
Anal and rectal abscess.....	566	1	0.1
Suppurative peritonitis.....	567.2	1	0.1
Rectal disorders (hemorrhoids).....	569.1, 569.49	2	0.2
Perforation of intestine.....	569.83	3	0.2
Portal hypertension.....	572.3	1	0.1
Hepatitis.....	573.3	1	0.1
Gallbladder disorders.....	574.00, 574.10, 574.20, 574.50, 574.51, 574.60	10	0.8
Acute cholecystitis.....	575.0	2	0.2
Biliary tract disorders.....	576.8	1	0.1
Acute pancreatitis.....	577.0	6	0.5
<u>Genitourinary Diagnoses</u>		32	2.4
Acute renal failure.....	584.5, 584.9	8	0.6
Chronic renal failure.....	585	1	0.1
Acute pyelonephritis.....	590.10, 590.80	2	0.2
Calculus of ureter.....	592.1	3	0.2
Disorder of kidney or ureter.....	593.9	1	0.1
Calculus of bladder.....	594.1	1	0.1
Cystitis.....	595.82	1	0.1
Bladder neck obstruction.....	596.0	1	0.1
Hematuria.....	599.7	1	0.1
Disorder of urinary tract.....	599.9	1	0.1
Hyperplasia of prostate.....	600.0, 600.1	9	0.7
Prostatocystitis.....	601.3	1	0.1
Urinary retention.....	788.20	1	0.1
Bladder/urethra injury.....	867.0	1	0.1
<u>Neurologic Diagnoses</u>			
<u>Stroke/transient cerebral ischemia/anoxic brain damage</u>		31	2.4
Subarachnoid hemorrhage.....	430	1	0.1
Intracerebral hemorrhage.....	431	1	0.1
Occlusion and stenosis of precerebral arteries.....	433.10, 433.11	5	0.4
Cerebral thrombosis with cerebral infarction.....	434.01, 434.11, 434.91	10	0.8
Transient cerebral ischemia.....	435.3, 435.8, 435.9	9	0.7
Acute, but ill-defined cerebrovascular disease (CVA).....	436	4	0.3
Concussion.....	850.0	1	0.1

**Table 9. Statewide Readmission Data, by Reason for Readmission *continued*
Total Hip and Knee Replacements**

Diagnosis	ICD.9.CM Code	# of Readmits	% of all Readmits
<u>Mental disorders</u>		13	1.0
Drug induced delirium	292.12, 292.81	3	0.2
Acute delirium	293.0	1	0.1
Schizo-affective type	295.70	1	0.1
Depressive disorder	296.23, 296.34, 311	3	0.2
Bipolar disorder	296.50, 296.7	2	0.2
Paranoid state	297.9	1	0.1
Anxiety disorders	300.00	1	0.1
Alcohol abuse	305.00	1	0.1
<u>Nervous system disorders</u>		18	1.4
Disorders of autonomic nervous system	337.9	1	0.1
Epilepsy	345.90	1	0.1
Migraine	346.90	1	0.1
Toxic encephalopathy	349.82	1	0.1
Mononeuritis	355.0, 355.8, 355.9	3	0.2
Disorders of vestibular system	386.00, 386.11, 386.30	7	0.5
Convulsions, not otherwise specified	780.39	4	0.3
<u>Musculoskeletal System Diagnoses</u>		111	8.5
Pyogenic arthritis	711.06	1	0.1
Rheumatoid arthritis	714.0	3	0.2
Osteoarthritis	715.35, 715.36, 715.90, 715.96	26	2.0
Polyarthritis	716.59	1	0.1
Ankylosis of joint, lower leg	718.56	3	0.2
Effusion of joint	719.06	2	0.2
Hemarthrosis (bleeding in joint)	719.16	2	0.2
Pain in joint	719.45, 719.46	11	0.8
Stiffness in joint	719.56	2	0.2
Unspecified joint disorder	719.65	1	0.1
Difficulty walking	719.76	1	0.1
Lumbosacral spondylosis	721.3	1	0.1
Lumbar disc displacement	722.10	1	0.1
Intervertebral disc disorders	722.52	1	0.1
Disorders of cervical region	723.1	1	0.1
Spinal stenosis – lumbar	724.02	1	0.1
Lumbago	724.2	2	0.2
Lumbosacral neuritis	724.4	1	0.1
Enthesopathy of knee	726.60	2	0.2
Synovitis	727.00	1	0.1
Muscular atrophy and rupture	728.83, 728.89	2	0.2
Myalgia and pain in limb	729.1, 729.5	7	0.5
Osteomyelitis of forearm	730.03	1	0.1
Pathologic fracture of femur neck	733.14	1	0.1
Aseptic necrosis	733.42, 733.49	2	0.2
Fracture of cervical	805.08	1	0.1
Fracture of femoral neck ¹	820.09, 820.20, 820.21, 820.8	8	0.6
Fracture of other parts of femur (shaft) ¹	821.00, 821.01, 821.20, 821.23, 821.29	10	0.8
Fracture of tibia and fibula ¹	823.02	1	0.1

¹These conditions were also defined as complications.

**Table 9. Statewide Readmission Data, by Reason for Readmission *continued*
Total Hip and Knee Replacements**

<i>Diagnosis</i>	<i>ICD.9.CM Code</i>	<i># of Readmits</i>	<i>% of all Readmits</i>
Musculoskeletal System Diagnoses <i>continued</i>			
Fracture of ankle	824.2, 824.8	2	0.2
Fracture of tarsal or metatarsal bones.....	825.0	1	0.1
Hip and thigh sprain	843.9	2	0.2
Knee sprain	844.1, 844.8, 844.9	8	0.6
Lower leg injury	959.7	1	0.1
<u>Device, implant, or graft complications</u>		134	10.3
Mechanical complication of internal orthopedic device, implant & graft ¹	996.4	100	7.7
Other complications due to internal joint prosthesis ¹	996.77	33	2.5
Other complications due to internal orthopedic device, implant & graft ¹	996.78	1	0.1
Other Diagnoses			
<u>Infections</u>		311	23.8
Intestinal infection due to clostridium difficile.....	008.45	17	1.3
Viral enteritis NOS.....	008.8	5	0.4
Septicemia	038.0, 038.19, 038.42, 038.43, 038.9	15	1.1
HIV Disease	042	1	0.1
Viral infection NOS.....	079.99	5	0.4
Bronchitis	466.0	2	0.2
Pneumonia	480.9, 482.1, 482.41, 482.9, 486	31	2.4
Flu with manifestations.....	487.8	1	0.1
Urinary tract infection	599.0	11	0.8
Cellulitis.....	682.3, 682.5, 682.6 ¹ , 682.7 ¹	23	1.8
Fever.....	780.6	7	0.5
Bacteremia	790.7	1	0.1
Infection & inflammatory reaction due to vascular device.....	996.62	2	0.2
Infection & inflammatory reaction due to indwelling urinary catheter.....	996.64	1	0.1
Infection & inflammatory reaction due to internal joint prosthesis ¹	996.66, 996.67	80	6.1
Infected post-surgical seroma ¹	998.51	3	0.2
Other post-surgical infection.....	998.59	104	8.0
Non-healing surgical wound ¹	998.83	2	0.2
<u>Diabetes/metabolic disorders</u>		42	3.2%
Diabetes with ketoacidosis.....	250.10, 250.11	2	0.2
Diabetes with neurological manifestations	250.60	1	0.1
Diabetes with other manifestations.....	250.80, 250.82	4	0.3
Other disorder or plasma protein metabolism	273.8	1	0.1
Gout	274.9	1	0.1
Disorders of iron metabolism.....	275.0	1	0.1
Hypercalcemia	275.42	1	0.1
Fluid and electrolyte imbalance.....	276.1, 276.5, 276.6, 276.7, 276.8	31	2.4

¹These conditions were also defined as complications.

**Table 9. Statewide Readmission Data, by Reason for Readmission *continued*
Total Hip and Knee Replacements**

<i>Diagnosis</i>	<i>ICD.9.CM Code</i>	<i># of Readmits</i>	<i>% of all Readmits</i>
<u>Other surgical complications</u>		76	5.8
Iatrogenic cerebral infarction or hemorrhage	997.02	2	0.2
Cardiac complications resulting from procedure	997.1	5	0.4
Respiratory complications resulting from procedure	997.3	2	0.2
Hemorrhage or hematoma complicating a procedure	998.11, 998.12, 998.13	45	3.4
Dehiscence or rupture of operation wound ¹	998.3	19	1.5
Other procedure complications not listed elsewhere	998.89	3	0.2
<u>Neoplasms</u>		7	0.5
Malignant neoplasm of esophagus	150.5	1	0.1
Malignant neoplasm of prostate	185	1	0.1
Malignant neoplasm of kidney	189.0	1	0.1
Malignant neoplasm of peritoneum	197.6	1	0.1
Malignant neoplasm of liver	197.7	1	0.1
Malignant lymphoma	202.80, 202.82	2	0.2
<u>Skin and subcutaneous tissue diagnoses</u>		13	1.0
Drug induced dermatitis	693.0	1	0.1
Erythema unspecified	695.9	1	0.1
Decubitus ulcer	707.0	5	0.4
Open wound of knee	891.1	1	0.1
Contusion of face, scalp, neck	920	1	0.1
Contusion of chest wall	922.1	1	0.1
Contusion of hip	924.01	1	0.1
Contusion of knee	924.11, 924.8	2	0.2
<u>Miscellaneous diagnoses</u>		28	2.1
Drug withdrawal syndrome	292.0	1	0.1
Alter consciousness	780.09	1	0.1
Syncope and collapse	780.2	10	0.8
Dizziness and giddiness	780.4	2	0.2
Malaise and fatigue	780.79	1	0.1
General symptoms	780.9	1	0.1
Poisoning	965.09, 965.4, 969.4	3	0.2
Angioneurotic edema	995.1	2	0.2
Allergy, unspecified	995.3	1	0.1
Vitreous touch syndrome	997.99	1	0.1
Arthrodesis status	v45.4	1	0.1
Rehabilitation procedure	v57.89	1	0.1
Chemotherapy encounter	v58.1	1	0.1
Other postsurgical aftercare	v58.49	2	0.2

¹These conditions were also defined as complications.

Appendices

ICD-9-CM Codes Used to Define Deep Joint Infection or Device Problem, Blood Clot Lung/Leg, and Wound Infection

Note: For an event to be assigned as a complication the following criteria must be met:

- Initial hospitalizations: diagnosis code in any secondary position; procedure codes in any secondary position and occurring after the date of primary total hip or knee replacement
- Readmissions: diagnosis code in principal position; procedure code in either principal or secondary position

Type of Complication

ICD.9.CM

DEEP JOINT INFECTION or DEVICE PROBLEM

<i>Device Problem</i>	<i>Diagnosis</i>
Mechanical complication of internal orthopedic device, implant, and graft.....	996.4
Complication due to internal joint prosthesis	996.77
Complication due to other internal orthopedic device, implant, and graft	996.78
Dislocation/Instability of the Hip	
Other derangement of joint, not elsewhere classified – pelvic region and thigh.....	718.85
Closed dislocation of hip	835.0x (x=0-3)
Open dislocation of hip	835.1x (x=0-3)
Dislocation/Instability of the Knee	
Other derangement of joint, not elsewhere classified – lower leg	718.86
Tear of medial cartilage or meniscus of knee, current.....	836.0
Tear of lateral cartilage or meniscus of knee, current.....	836.1
Other tear of cartilage or meniscus of knee, current.....	836.2
Dislocation of patella, closed	836.3
Dislocation of patella, open.....	836.4
Other dislocation of knee, closed.....	836.5x (x=0-9)
Other dislocation of knee, open	836.6x (x=0-9)
Hip Fracture	
Malunion of fracture	733.81
Nonunion of fracture	733.82
Transcervical fracture, closed; intracapsular section, unspecified.....	820.00
Transcervical fracture, closed; epiphysis (separation) (upper)	820.01
Transcervical fracture, closed; midcervical section	820.02
Transcervical fracture, closed; base of neck	820.03
Transcervical fracture, closed; other.....	820.09
Transcervical fracture, open; intracapsular section, unspecified.....	820.10
Transcervical fracture, open; epiphysis (separation) (upper)	820.11
Transcervical fracture, open; midcervical section.....	820.12
Transcervical fracture, open; base of neck.....	820.13
Transcervical fracture, open; other	820.19
Pertrochanteric fracture, closed; trochanteric section, unspecified	820.20
Pertrochanteric fracture, closed; intertrochanteric section	820.21
Pertrochanteric fracture, closed; subtrochanteric section.....	820.22
Pertrochanteric fracture, open; trochanteric section, unspecified.....	820.30
Pertrochanteric fracture, open; intertrochanteric section.....	820.31
Pertrochanteric fracture, open; subtrochanteric section	820.32
Fracture, unspecified part of neck of femur, closed.....	820.8
Fracture, unspecified part of neck of femur, open	820.9
Fracture, unspecified part of femur, closed	821.00
Fracture, shaft, closed	821.01
Fracture, unspecified part of femur, open.....	821.10
Fracture, shaft, open.....	821.11
Knee Fracture	
Malunion of fracture	733.81
Nonunion of fracture	733.82
Fracture femur, lower end, unspecified part, closed.....	821.20
Fracture, condyle, femoral, closed.....	821.21
Fracture, epiphysis, lower (separation), closed	821.22
Supracondylar fracture of femur, closed.....	821.23
Fracture, lower end; other, closed	821.29
Fracture femur, lower end, unspecified part, open	821.30
Fracture, condyle; femoral, open	821.31
Fracture, epiphysis; lower (separation), open.....	821.32
Supracondylar fracture of femur, open	821.33
Fracture, lower end; other, open.....	821.39
Fracture of patella, closed	822.0
Fracture of patella, open	822.1

**ICD-9-CM Codes Used to Define Deep Joint Infection or Device Problem,
Blood Clot Lung/Leg, and Wound Infection (continued)**

Type of Complication	ICD.9.CM
JOINT INFECTION/DEVICE PROBLEM continued	
Knee Fracture continued	Diagnosis
Fracture upper end, closed; tibia alone	823.00
Fracture, upper end, closed; fibula alone	823.01
Fracture, upper end, closed; fibula with tibia	823.02
Fracture, upper end, open; tibia alone	823.10
Fracture, upper end, open; fibula alone	823.11
Fracture, upper end, open; fibula with tibia	823.12
Fracture, shaft, closed; tibia alone	823.20
Fracture, shaft, closed; fibula alone	823.21
Fracture, shaft, closed; fibula with tibia	823.22
Fracture, shaft, open; tibia alone	823.30
Fracture, shaft, open; fibula alone	823.31
Fracture, shaft, open; fibula with tibia	823.32
Fracture, unspecified part, closed; tibia alone	823.80
Fracture, unspecified part, closed; fibula alone	823.81
Fracture, unspecified part, closed; fibula with tibia	823.82
Fracture, unspecified part, open; tibia alone	823.90
Fracture, unspecified part, open; fibula alone	823.91
Fracture, unspecified part, open; fibula with tibia	823.92
Deep Joint Infection	
Acute osteomyelitis of pelvic region and thigh	730.05
Acute osteomyelitis of lower leg	730.06
Unspecified of osteomyelitis pelvic region and thigh	730.25
Unspecified of osteomyelitis lower leg	730.26
Unspecified infection of bone of pelvic region and thigh	730.95
Unspecified infection of bone of lower leg	730.96
Infection and inflammatory reaction due to internal joint prosthesis	996.66
Infection and inflammatory reaction due to orthopedic device, implant, and graft	996.67
Hip – Revision	Procedure
Revision of hip replacement	81.53
Hip – Reduction of Fracture	
Closed reduction of fracture without internal fixation, femur	79.05
Closed reduction of fracture with internal fixation, femur	79.15
Open reduction of fracture without internal fixation, femur	79.25
Open reduction of fracture with internal fixation, femur	79.35
Hip – Reduction of Dislocation	
Closed reduction of dislocation of hip	79.75
Open reduction of dislocation of hip	79.85
Hip – Other Repair	
Sequestrectomy, femur	77.05
Removal of implanted devices from bone, femur	78.65
Arthrotomy for removal of prosthesis, hip	80.05
Division of joint capsule, ligament, or cartilage, hip	80.45
Knee – Revision	
Revision of knee replacement	81.55
Knee – Reduction of Fracture	
Closed reduction of fracture without internal fixation, femur	79.05
Closed reduction of fracture without internal fixation, tibia and fibula	79.06
Closed reduction of fracture with internal fixation, tibia and fibula	79.16
Open reduction of fracture without internal fixation, femur	79.25
Open reduction of fracture without internal fixation, tibia and fibula	79.26
Open reduction of fracture with internal fixation, femur	79.35
Open reduction of fracture with internal fixation, tibia and fibula	79.36
Knee – Reduction of Dislocation	
Closed reduction of dislocation of knee	79.76
Open reduction of dislocation of knee	79.86
Knee – Other Repair	
Sequestrectomy, patella	77.06
Removal of implanted devices from bone, patella	78.66
Arthrotomy of removal of prosthesis, knee	80.06
Division of joint capsule, ligament, or cartilage, knee	80.46

**ICD-9-CM Codes Used to Define Deep Joint Infection or Device Problem,
Blood Clot Lung/Leg, and Wound Infection (continued)**

Type of Complication	ICD.9.CM
BLOOD CLOT LUNG/LEG	
Deep Vein Thrombosis (DVT)	Diagnosis
Phlebitis and thrombophlebitis of femoral vein (deep) (superficial)	451.11
Phlebitis and thrombophlebitis of other deep vessels of lower extremities.....	451.19
Phlebitis and thrombophlebitis of iliac vein.....	451.81
Venous embolism and thrombosis of other specified veins.....	453.8
Venous embolism and thrombosis of unspecified site.....	453.9
Peripheral vascular complications	997.2
	Procedure
Incision of lower limb veins	38.09
Pulmonary Embolism (PE)	Diagnosis
Iatrogenic pulmonary embolism and infarction	415.11
Other pulmonary embolism and infarction	415.19
	Procedure
Incision of other thoracic vessels.....	38.05
WOUND INFECTION	
Wound Related Infection	Diagnosis
Other cellulitis and abscess of leg, except foot.....	682.6
Other cellulitis and abscess of foot, except toes.....	682.7
Unspecified local infection of skin and subcutaneous tissue.....	686.9
Open wound of hip and thigh without mention of complication.....	890.0
Open wound of hip and thigh complicated.....	890.1
Open wound of hip and thigh with tendon involvement	890.2
Open wound of knee, leg [except thigh], and ankle without mention of complication.....	891.0
Open wound of knee, leg [except thigh], and ankle complicated.....	891.1
Open wound of knee, leg [except thigh], and ankle with tendon involvement	891.2
Multiple and unspecified open wound of lower limb without mention of complication	894.0
Multiple and unspecified open wound of lower limb complicated	894.1
Multiple and unspecified open wound of lower limb with tendon involvement.....	894.2
Disruption of operation wound	998.3
Infected postoperative seroma	998.51
Non-healing surgical wound	998.83
	Procedure
Excisional debridement of wound, infection, or burn	86.22
Non-excisional debridement of wound, infection, or burn.....	86.28
Other irrigation of wound	96.59

Candidate Variable Descriptions

Note: Not all of the different variable constructs developed and considered are in the following list; only those that were tested in the development sample and/or used in the final risk models are included.

- Age: *Tested as a continuous variable*
- Age-Squared: *Tested as a continuous variable*
- Age/Sex Category (*Female < 65, Female ≥ 65 to < 75, Female ≥ 75, Male < 65, Male ≥ 65 to < 75, Male ≥ 75*)
- Age/Sex/Hip/Knee Category (*Female < 65, total hip replacement-81.51; Female ≥ 65 to < 75, total hip replacement, Female ≥ 75, total hip replacement, Male < 65, total hip replacement, Male ≥ 65 to < 75, total hip replacement, Male ≥ 75, total hip replacement; Female < 65, knee replacement-81.54; Female ≥ 65, knee replacement; Male < 75, knee replacement, Male ≥ 75, knee replacement*)
- Alzheimer's and/or Parkinson's Diseases (*no, yes: 331.0, 332.0, 332.1, 348.9*)
- Anemia (*no, yes: 280, 281, 282.0, 282.1, 282.2, 282.3, 282.4, 282.5, 282.60, 282.61, 282.62, 282.63, 282.69, 282.7, 282.8, 282.9, 283, 284, 285.0, 285.2, 285.8*)
- Atlas Outcomes™ Predicted Length of Stay (MQPredLOS): *Tested as a continuous variable and a categorical variable*
- Bilateral or multiple joint procedures of the hip or leg (*no, yes: DRG 471*)
- Bone Quality – Poor (*no, yes: 268.2, 733.00, 733.01, 733.02, 733.03, 733.09*)
- Cancer (*no, yes: 140.0-195.8, 196.0-199.1, 200.0-208.9, 230.0-239.9*)
- Cardiomyopathy (*no, yes: 425.3, 425.4, 425.8, 425.9*)
- Chronic Obstructive Pulmonary Disease (*no, yes: 491.20, 491.21, 492.0, 492.8, 496, 506.4, 518.2*)
- Chronic Renal Failure (*no, yes: 585*)
- Coagulation Defects (*no, yes: 286.0, 286.1, 286.2, 286.3, 286.4, 286.5, 286.6, 286.7, 286.9, 287.1, 287.2, 287.3, 287.4, 287.5, 287.8, 287.9, 289.99*)
- Coronary Atherosclerosis (*no, yes: 414.0*)
- Depression, Psychoses, and Dementia (*no, yes: 290.0, 290.20, 290.21, 290.3, 295.00, 295.01, 295.02, 295.03, 295.04, 295.05, 295.10, 295.11, 295.12, 295.13, 295.14, 295.15, 295.20, 295.21, 295.22, 295.23, 295.24, 295.25, 295.30, 295.31, 295.32, 295.33, 295.34, 295.35, 295.40, 295.41, 295.42, 295.43, 295.44, 295.45, 295.50, 295.51, 295.52, 295.53, 295.54, 295.55, 295.60, 295.61, 295.62, 295.63, 295.64, 295.65, 295.70, 295.71, 295.72, 295.73, 295.74, 295.75, 295.80, 295.81, 295.82, 295.83, 295.84, 295.85, 295.90, 295.91, 295.92, 295.93, 295.94, 295.95; 296.00, 296.01, 296.02, 296.03, 296.04, 296.05, 296.06, 296.10, 296.11, 296.12, 296.13, 296.14, 296.15, 296.16, 296.20, 296.21, 296.22, 296.23, 296.24, 296.25, 296.26, 296.30, 296.31, 296.32, 296.33, 296.34, 296.35, 296.36, 296.40, 296.41, 296.42, 296.43, 296.44, 296.45, 296.46, 296.50, 296.51, 296.52, 296.53, 296.54, 296.55, 296.56, 296.60, 296.61, 296.62, 296.63, 296.64, 296.65, 296.66, 296.7, 296.80, 296.81, 296.82, 296.89, 296.90, 296.99; 297.0, 297.1, 297.2, 297.3, 297.8, 297.9; 298.0, 298.1, 298.2, 298.3, 298.4, 298.8, 298.9; 300.4, 301.12, 311)*)
- Diabetes Category (*none, without complications-250.00, 250.01, 250.02, 250.03; with complications-see below for relevant ICD-9-CM codes*)
- Diabetes with Complications (*no, yes: 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*)
- Discharge Status Category (*rehabilitation unit/facility, skilled nursing facility, home, other*)
- Gait Abnormality (*no, yes: 719.7, 781.2, 781.3*)
- Heart Failure (*no, yes: 398.91, 428.0, 428.1, 428.9*) *Note: For those cases having one of the noted heart failure codes and a hypertension with congestive heart failure code (402.x1, 404.x1, 404.x3) in the same record, only the hypertension code was used.*
- Heart Valve Diseases (*no, yes: 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, 397.9, 424.0, 424.1, 424.2, 424.3, 424.90, 424.91, 424.99*) *Note: Congenital heart anomalies not included.*
- History of Myocardial Infarction (Old Myocardial Infarction) (*no, yes: 412*)
- History of Pacemaker (*no, yes: V45.00, V45.01, V45.02*)
- History of Thrombosis (*no, yes: V12.51, V12.52*)
- Hypertension with Complications (*no, yes: 402.01, 402.11, 402.91, 403.01, 403.11, 403.91, 404.01, 404.02, 404.03, 404.11, 404.12, 404.13, 404.91, 404.92, 404.93, 405.01, 405.09, 405.11, 405.19, 405.91, 405.99*)

Appendix B

Candidate Variable Descriptions *continued*

- Late Effect of Stroke (*no, yes: 438.0, 438.12, 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, 438.81, 438.82, 438.89, 438.9*)
- Medical Assistance (*no, yes*)
- Obesity (*no, yes: 278.00, 278.01*)
- Obesity/Hip/Knee Category (*No obesity with total hip replacement-81.51; Unspecified obesity with total hip replacement; Morbid obesity with total hip replacement; No obesity with knee replacement-81.54; Unspecified obesity with knee replacement; Morbid obesity with knee replacement*)
- Obesity – Morbid (*no, yes: 278.01*)
- Pennsylvania Resident (*no, yes*)
- Peripheral Vascular Disease (*no, yes: 443.0, 443.1, 443.81, 443.89, 443.9*)
- Race (*Black or African American, White, Other*)
- Tobacco Use Disorder (*no, yes: 305.1*)
- Total Hip Replacement (*no, yes: 81.51*)
- Underlying Disease Category
(*total hip replacement with principal diagnosis of arthropathy, aseptic necrosis, and/or rheumatoid arthritis; total hip replacement with principal diagnosis of osteoarthritis and/ other; knee replacement with principal diagnosis of arthropathy, aseptic necrosis, and/or other; knee replacement with principal diagnosis of osteoarthritis and/or rheumatoid arthritis*)

ICD-9-CM definitions for underlying disease categories:

Arthropathy (hip-716.15, 716.16, 716.45, 716.55, 716.59, 716.85, 716.95; knee-716.15, 716.16, 716.36, 716.46, 716.56, 716.59, 716.86, 716.96)

Aseptic Necrosis (hip-733.40, 733.41, 733.42, 733.49; knee-733.40, 733.42, 733.43, 733.49)

Osteoarthritis (hip-715.09, 715.13, 715.15, 715.16, 715.25, 715.34, 715.35, 715.36, 715.37, 715.89, 715.90, 715.91, 715.95, 715.96, 715.98; knee-715.00, 715.09, 715.15, 715.16, 715.26, 715.35, 715.36, 715.38, 715.89, 715.90, 715.95, 715.96, 715.96, 715.98)

Rheumatoid Arthritis (714.0, 714.1, 714.4, 714.9)

Other: total hip or knee replacement with any principal diagnosis codes other than arthropathy, aseptic necrosis, osteoarthritis, and/or rheumatoid arthritis

Example 1: Calculating the Risk-Adjusted Post-Operative Length of Stay Using Linear Regression

<i>Post-Operative Length of Stay for a Surgeon</i>	
Total Cases:	Number of cases for a surgeon after exclusions (equal to n).
Actual Mean Post-Operative Length of Stay:	Mean of the post-operative length of stays of all cases.
Expected Mean Post-Operative Length of Stay:	<p>Mean of the predicted post-operative length of stays of all cases.</p> <p>Step 1: Calculate each case's predicted post-operative length of stay (PredPOLOS) using the constant (β_0) and the regression coefficients (β's) that correspond to each respective risk factor (x) relevant to that particular patient:</p> $\beta X = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \dots + \beta_n x_n$ $= 7.265738400 + (0.000061295)(x_1) + (0.440227686)(x_2) + (0.267458334)(x_3) \dots + \beta_n x_n$ <p>where</p> <ul style="list-style-type: none"> x_1 = Age-Squared x_2 = Alzheimer's and/or Parkinson's x_3 = Anemia x_n = Coefficients for each of the remaining risk factors <p style="text-align: center;">PredPOLOS = βX</p> <p>Step 2: Calculate the mean PredPOLOS for a surgeon (expected post-operative length of stay):</p> $\text{Mean PredPOLOS} = \frac{\sum \text{PredPOLOS}}{n}$
Risk-Adjusted Post-Operative Length of Stay:	$= \frac{\text{Mean Actual LOS}}{\text{Mean PredPOLOS}} \left(\text{Statewide Mean Actual Post-Op LOS} \right)$

Example 2a: Calculating the Expected or Predicted Value Using Logistic Regression

Blood Clot Lung/Leg for a Hospital

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

Actual Number of Blood Clots Lung/Leg: Total number of cases with a blood clot lung/leg.

Expected Number of Blood Clots Lung/Leg: Sum of all the probabilities of a blood clot lung/leg for the hospital.

Calculate the predicted probability of blood clot lung/leg for each case (P_{Clot}) using the constant (β_0) and the regression coefficients (β 's) that correspond to each respective risk factor (x) relevant to that particular patient:

$$\begin{aligned}\beta X &= \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 \\ &= -5.1667 + (0.0126)(x_1) + (1.2905)(x_2) + (0.4130)(x_3) + (-0.2635)(x_4)\end{aligned}$$

where

- x_1 = Age
- x_2 = Coagulation Defects
- x_3 = Heart Valve Diseases
- x_4 = Total Hip Replacement

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

where $e \approx 2.7182818285$

Example 2b: Statistical Rating

Blood Clot Lung/Leg for a Hospital continued

Z score:
$$\frac{(\text{Actual Number of blood clots for the hospital} - \text{Expected number of blood clots for the hospital})}{\text{Standard Deviation of blood clot lung/leg}}$$

To calculate the standard deviation of blood clot lung/leg (SD_{BC}):

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

$$\text{VARPAT} = P_{\text{Clot}}(1 - P_{\text{Clot}})$$

Step 2: Compute the estimated variance of the hospital's probability of blood clot (SUMVAR):

SUMVAR = Sum of VARPAT across all cases

Step 3: The standard deviation of blood clot lung/leg (SD_{BC}) is the square root of SUMVAR

$$\text{SD}_{\text{BC}} = \sqrt{\text{SUMVAR}}$$

p-value (two sided): The p-value is determined using a Z score table.

Statistical Rating: If the p-value < 0.05 and the Z score > 0, then more deaths than expected (denoted as "●")
If the p-value < 0.05 and the Z score < 0, then fewer deaths than expected (denoted as "○")
Otherwise, the number of blood clots lung/leg were within the expected range (denoted as "⊙")

Expected Range: Lower limit = Expected blood clots lung/leg - 1.96 (standard deviation of blood clots lung/leg)
Upper limit = Expected blood clots lung/leg + 1.96 (standard deviation of blood clots lung/leg)

Example 3: Case-Mix Adjustment

Average Hospital Charge for Knee Replacements*

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

Average Charge: Mean of the charges of all cases within a particular DRG group.

Case-Mix Adjusted Charge: Step 1: Calculate **relative weights** for each of the two groups for each of the 9 regions

- a. Calculate relative weight for DRG 209 for Region 1:

$$\begin{aligned} \text{Relative Weight (RW}_1\text{)} &= \frac{\text{AvgChg}_{\text{DRG 209}} \text{ for Region 1}}{\text{Region 1 AvgChg}_{\text{DRG209} + \text{DRG471}}} \\ &= \frac{\$21,205}{\$21,523} \\ &= 0.98523 \end{aligned}$$

- b. Calculate relative weight for DRG 471 for Region 1:

$$\begin{aligned} \text{Relative Weight (RW}_2\text{)} &= \frac{\text{AvgChg}_{\text{DRG471}} \text{ for Region 1}}{\text{Region 1 AvgChg}_{\text{DRG209} + \text{DRG471}}} \\ &= \frac{\$31,774}{\$21,523} \\ &= 1.47628 \end{aligned}$$

Step 2: Calculate the **case-mix index** for Hospital A in Region 1

$$\begin{aligned} \text{Case-Mix Index for Hospital A} &= \frac{(\# \text{ of Cases}_{\text{DRG209}} \times \text{RW}_1) + (\# \text{ of Cases}_{\text{DRG471}} \times \text{RW}_2)}{\text{Total cases in DRGs 209 and 471 for Hospital A}} \\ &= \frac{(100 \times 0.98523) + (100 \times 1.47628)}{200} \\ &= \frac{98.523 + 147.628}{200} \\ &= 1.2308 \end{aligned}$$

Step 3: Calculate the **case-mix adjusted charge** for Hospital A

$$\begin{aligned} \text{Case-Mix Adjusted Charge for Hospital A} &= \frac{\text{Hospital's Average Charge}_{\text{DRG209} + \text{DRG471}}}{\text{Case-Mix Index}} \\ &= \frac{\$23,000}{1.2308} \\ &= \$18,687 \end{aligned}$$

*Case-mix adjustment methodology was only applied to the average charge analysis for knee replacements.

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