TECHNICAL NOTES
for Spinal Fusion

June
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Pennsylvania Health Care Cost Containment Council
Report Period: Calendar Year 2014
January 1, 2014 through December 31, 2014 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 spinal fusion surgery for discharges from January 1, 2014 through December 31, 2014. 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 spinal fusion procedure in a Pennsylvania general acute care (GAC) hospital.

- The following measures are reported:

    - Total number of spinal fusion cases for hospitals and surgeons, including elective and non-elective[1] cases.
    - Risk-adjusted in-hospital complication. This measure is reported for hospitals with five or more cases in the analysis.
    - Risk-adjusted readmission for a complication. This measure is reported for hospitals with five or more cases in the analysis.
    - Risk-adjusted any unplanned readmission. 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 in the analysis.
    - Calendar year 2013 average Medicare payment is reported for hospitals with at least 11 cases in the analysis.
    - Calendar year 2013 average hospital charge (case-mix adjusted) is reported for the cases in the 2013 average Medicare payment measure. Average charge is reported for hospitals with 11 or more cases in the analysis.

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 spinal fusion surgery.

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

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 in-hospital complication, readmission for complication, any unplanned readmission, average charge, and average Medicare payment analyses.

DATA COLLECTION AND VERIFICATION

The data for the spinal fusion report, obtained from the inpatient UB-04 (Uniform Billing) form, was submitted electronically to PHC4 by Pennsylvania GAC hospitals that performed spinal fusion procedures 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 spinal fusion 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, 2014 and December 31, 2014 who underwent spinal fusion surgery, 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.

- 81.00 Spinal fusion, not otherwise specified
- 81.01 Atlas-axis spinal fusion
- 81.02 Other cervical fusion of the anterior column, anterior technique
- 81.03 Other cervical fusion of the posterior column, posterior technique
- 81.04 Dorsal and dorsolumbar fusion of the anterior column, anterior technique
- 81.05 Dorsal and dorsolumbar fusion of the posterior column, posterior technique
- 81.06 Lumbar and lumbosacral fusion of the anterior column, anterior technique
- 81.07 Lumbar and lumbosacral fusion of the posterior column, posterior technique
- 81.08 Lumbar and lumbosacral fusion of the anterior column, posterior technique

Exclusion Criteria

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

- In-hospital complication
- Readmission for a complication
- Any unplanned readmission
- Average hospital charge

Additional exclusions for the in-hospital complication analysis included:

- Cases with invalid or missing discharge status.

Additional exclusions for the readmission for a complication analysis included:

- Cases with invalid or missing discharge status.
- Patients who died during the hospitalization in which the surgery was performed.
- Patients who left against medical advice.
- Cases with invalid data (i.e., social security number), which could not be linked to subsequent hospitalizations.
- Out-of-state residents, because these patients could undergo a spinal fusion surgery 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 cases within 90 days that met the study population criteria.

Additional exclusions for the any unplanned readmission analysis included:

- Cases with invalid or missing discharge status.
- Patients who died during the hospitalization in which the surgery was performed.

* 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).

- Patients who left against medical advice.
- Patients who were transferred to another Pennsylvania acute care facility.
- Cases with invalid data (i.e., social security number), which could not be linked to subsequent hospitalizations.
- Out-of-state residents, because these patients could undergo a spinal fusion surgery 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 cases within 30 days that met the study population criteria.

Additional exclusions for average hospital charge included:

- Cases with missing or invalid charges.
- Cases in low volume MS-DRGs, including when a particular combination of PA region and MS-DRG 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).

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

MEASURES REPORTED

Number of Cases

The number of total spinal fusion 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 children's hospitals, 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 spinal fusion surgeries were performed during the same hospitalization, the case was only counted once. Note that if two spinal fusions were performed during the same hospitalization and two different surgeons performed the fusions, an exception was made when counting surgeon volume. Each fusion was counted once for each surgeon.

Risk-Adjusted Ratings

Risk-adjusted ratings are reported for in-hospital complication, readmission for a complication, and any unplanned readmission. The rating identifies whether the hospital's observed rate of the outcome of interest was significantly higher than, significantly lower than, or not significantly different than expected based on patient risk factors.

In-hospital complication. An in-hospital complication was defined as a surgical complication (device, implant, graft, or wound) or death occurring during the hospitalization in which the spinal fusion surgery was performed (also referred to as the index hospitalization). In-hospital complication is a dichotomous (yes/no) outcome. As such, a complication was counted once when: 1) one of the ICD-9-CM codes listed in Appendix B was a secondary diagnosis that was *not* present on admission, as determined by the present on admission (POA) indicator in the patient record, and/or 2) the patient died, as determined by a discharge status of "20."

Readmission for a complication. A readmission for a complication was defined as a rehospitalization with a principal diagnosis of a surgical complication (device, implant, graft, or wound; see Appendix B) to any general or specialty acute care hospital in Pennsylvania within 30 or 90 days of discharge (depending on the complication) from the index hospitalization.

- Surgical site bleeding or wound complication within 30 days of the index hospitalization discharge date.
- Mechanical complication or infection of device, implant, or graft within 90 days of the index hospitalization discharge date.

A hospitalization that resulted in more than one readmission within 90 days was counted only once even though it resulted in multiple readmissions. If, over the study period, a patient had multiple discharges for spinal fusion, each discharge was independently investigated to determine whether it had a readmission within 90 days of that discharge with one exception. If a second hospitalization for spinal fusion occurred within 90 days of the first or index hospitalization, the second hospitalization was excluded from the readmission analysis.

Any unplanned readmission. An unplanned readmission was defined as a rehospitalization to any general or specialty acute care hospital in Pennsylvania within 30 days of the index hospitalization discharge date. 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 designed to identify

[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).

admissions for procedures that are typically planned so they will not be counted as a readmission.[1]

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 spinal fusion, 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 spinal fusion occurred within 30 days of the first or index hospitalization, the second hospitalization was excluded from the readmission 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 spinal fusion surgery 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.

Calendar Year 2013 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 2013, since this was the most recent Medicare payment data available.

The Medicare payment data for 2013 was provided to PHC4 by the Centers for Medicare and Medicaid Services (CMS) and then matched by PHC4 to the 2013 spinal fusion surgery 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 received 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 2013 Average Hospital Charge for Medicare Fee-for-Service Cases

Case-mix adjusted average charge is reported for the Medicare cases included in the 2013 average Medicare payment. While the same cases included in the average Medicare payment

[1] 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.

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 an event (i.e., in-hospital complication, readmission for a complication, or any unplanned readmission). Each model was a mathematical formula used to ultimately predict a patient's probability of the event based on relevant risk factors. Cases with these risk factors were given more "credit" in the calculation, leading to a higher predicted probability of the event. A hospital's predicted rate was the average predicted probability across all its spinal fusion surgery discharges in the analysis. The ratings indicate whether the hospital's in-hospital complication, readmission for a complication, or any unplanned readmission rates were 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

A separate model was developed for each outcome measure (i.e., in-hospital complication, readmission for a complication, or any unplanned readmission). For modeling each of the outcomes, the reference database included spinal fusion surgery discharges from January 1, 2014 through December 31, 2014 (after exclusions). Data Table 1 displays frequencies for the datasets and statewide outcomes.

Identifying potential risk factors. The first step in building the models was to identify potential risk factors, that is, factors that potentially contributed to the event. 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 C.

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 two of the three 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.

- 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 event. 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

* 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.

frequency of the outcome. The c-statistics for the in-hospital complication, readmission for a complication, and any unplanned readmission models are listed in Data Tables 3, 4 and 5.

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 (i.e., in-hospital complication, readmission for a complication, or any unplanned 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 in-hospital complication model, the odds ratio for deformity of the spine indicates that patients with this factor were 84.8% more likely to experience an in-hospital complication than patients without this factor. The coefficients and odds ratios for each risk factor included in the in-hospital complication, readmission for a complication, and any unplanned readmission models are listed in Data Tables 3, 4, and 5.

CALCULATING HOSPITAL-SPECIFIC OUTCOMES

Separate analyses were performed to determine, for each hospital, the actual percent of in-hospital complication, readmission for a complication, and any unplanned readmission. 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 percent of each outcome (i.e., in-hospital complication, readmission for a complication, and any unplanned readmission) was determined by dividing the number of hospitalizations for which the patient experienced the outcome of interest, by the total number of hospitalizations included in the outcome 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 the outcome occurring) 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 in-hospital complication, readmission for a complication, and any unplanned readmission 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., in-hospital complication vs. no in-hospital complication). In other words, the response was dichotomous.
- The probability of the event (e.g., in-hospital complication) 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 in-hospital complications 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., in-hospital complication) that were observed (i.e., a = 1 in-hospital complication, a = 2 in-hospital complications, 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 of in-hospital complication) for a particular hospital.

The rating process evaluated both fewer than expected as well as greater than expected in-hospital complications. Thus, a two-tailed test was used. In the example above (3 in-hospital complications out of 40), the probability associated with the left-hand tail was the sum of the probability for 0, 1, 2, or 3 in-hospital complications 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 spinal fusion surgery report, a Type I error would have occurred when the difference between the actual in-hospital complication percent and the expected in-hospital complication 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 in-hospital complication 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 in-hospital complication percent was less than expected, the hospital was assigned the symbol "○" (as shown in the spinal fusion report) to indicate that the in-hospital complication percent was significantly less than expected.
    - If the actual in-hospital complication percent was higher than expected, the hospital was assigned the symbol "●" (as shown in the spinal fusion report) to indicate that the in-hospital complication 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 in-hospital complication percent and the actual in-hospital complication percent was *not* statistically significant. It *cannot be concluded* that the actual in-hospital complication percent for that particular hospital was different from the expected in-hospital complication percent derived from the particular hospital's risk profile. In this case the hospital was assigned the symbol "⊙" (as shown in the spinal fusion report).

See Appendix C for an example of calculation of actual and expected in-hospital complication 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. 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 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 combination based on the hospital's geographic location and the MS-DRG assignment for the case. Then cases in PA region/MS-DRG combinations with less than 10 cases were excluded. Then trimming was performed.

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. 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 x IQR)*

Upper Trim Point = *Q3 + (3.0 x IQR)*

Determining Actual Charges

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

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 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 2014 Data

	Cases	Actual #	Actual %
Total Number of Cases	21,393		
In-Hospital Complications*	17,827	582	3.3%
Readmission for a Complication*	16,005	365	2.3%
Any Unplanned Readmission*	16,000	857	5.4%

	Cases	Actual Average Charge
Average Charge*	17,487	$100,431

CY 2013 Data

	Cases	Actual Average Medicare FFS Payment
Average Medicare Fee-for-Service (FFS) Payment*	3,002	$23,533

	Cases	Actual Average Charge for Medicare Cases
Average Charge for Medicare Cases*	2,909	$103,852

* The number of cases in the analysis.

DATA TABLES

TABLE 2. EXCLUSION DATA

Table 2A. Complication/Readmission Exclusions (CY 2014 Data)

	In-Hospital Complication		Readmission for a Complication		Any Unplanned Readmission	
	#	%	#	%	#	%
Total cases before exclusions	21,393	100.0%	21,393	100.0%	21,393	100.0%
Clinically complex cases excluded[1]	3,566	16.7%	3,566	16.7%	3,566	16.7%
Elective cases (total minus clinically complex)	17,827	83.3%	17,827	83.3%	17,827	83.3%
Other exclusions						
• *Cases with invalid or missing discharge status*	0	0.0%	0	0.0%	0	0.0%
• *Patients who died during the hospitalization in which the surgery was performed*	*NA*[2]	–	20	0.1%	20	0.1%
• *Patients who left against medical advice*	*NA*	–	11	0.1%	11	0.1%
• *Patients transferred to another acute care facility*	*NA*	–	*NA*	–	50	0.2%
• *Cases with invalid data*[3]	*NA*	–	143	0.7%	143	0.7%
• *Out-of-state residents*[4]	*NA*	–	1,586	7.4%	1,583	7.4%
• *Second index hospitalization within 90 days*	*NA*	–	62	0.3%	*NA*	–
• *Second index hospitalization within 30 days*	*NA*	–	*NA*	–	20	0.1%
Total exclusions	3,566	16.7%	5,388	25.2%	5,393	25.2%
Total cases remaining in analysis	**17,827**	**83.3%**	**16,005**	**74.8%**	**16,000**	**74.8%**

Table 2B. Average Charge Exclusions (CY 2014 Data)

	Cases	
	#	%
Total cases before exclusions	21,393	100.0%
Exclusions:		
• *Clinically complex cases*[1]	*3,566*	*16.7%*
• *Cases with missing or invalid charges*	*49*	*0.2%*
• *Cases in low volume MS-DRGs*[5]	*3*	*<0.1%*
• *Cases that were charge outliers*[6]	*288*	*1.3%*
Total exclusions	*3,906*	*18.3%*
Total cases remaining in analysis	**17,487**	**81.7%**

[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] NA indicates that the exclusion does not apply to this measure. See Exclusion section for more detail.

[3] Cases with invalid data (i.e., social security number) that could not be linked to subsequent hospitalizations.

[4] Out-of-state residents were excluded because such patients could undergo a spinal fusion surgery 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.

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

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

DATA TABLES

TABLE 3. IN-HOSPITAL COMPLICATION MODEL FOR SPINAL FUSION SURGERY

The c-statistic for the model is 0.67648.

Predictor	Coefficient	Odds Ratio*	p-value
Intercept	-0.6661		
Age (continuous)*	-0.1371	0.504	0.0197
Age Over 30 (continuous)*	0.1669	2.304	0.0065
INR ≥1.21	0.9648	2.624	0.0003
WBC ≥11.0 10^9/L	0.4278	1.534	0.0023
Deformity of Spine	0.6143	1.848	<0.0001
Spinal Stenosis without Spondylolisthesis	0.6633	1.941	<0.0001
Spondylolisthesis	0.5201	1.682	<0.0001

TABLE 4. READMISSION FOR A COMPLICATION MODEL FOR SPINAL FUSION SURGERY

The c-statistic for the model is 0.67140.

Predictor	Coefficient	Odds Ratio*	p-value
Intercept	-5.5578		
Age (continuous)*	0.0151	1.079	0.0006
Female	0.2355	1.266	0.0328
Black non-Hispanic	0.3854	1.470	0.0427
Poverty Rate (continuous)*	0.0156	1.081	0.0151
Glucose ≥136 mg/dL	0.3121	1.366	0.0137
INR ≥1.11	0.6581	1.931	0.0033
WBC ≥11.0 10^9/L	0.5202	1.682	0.0015
Complex Fusion	0.5752	1.777	<0.0001
Mental Disorders	0.3760	1.457	0.0010
Morbid Obesity	0.8120	2.252	<0.0001

* Odds ratios for “Age” and “Age Over 30” are calculated at units of 5 and odds ratio for “Poverty Rate” is calculated at 5%. Using “Age Over 30” as an example, the risk for an in-hospital complication is about 16% higher for patients age 35 than for patients age 30.

DATA TABLES

TABLE 5. ANY UNPLANNED READMISSION MODEL FOR SPINAL FUSION SURGERY

The c-statistic for the model is 0.70330.

Predictor	Coefficient	Odds Ratio*	p-value
Intercept	-4.2576		
Age (continuous)*	0.0067	1.034	0.5054
Age Over 50 (continuous)*	0.0299	1.161	0.0194
Black non-Hispanic	0.3062	1.358	0.0179
Glucose ≥136 mg/dL	0.2976	1.347	0.0004
INR ≥1.11	0.7915	2.207	<0.0001
WBC ≥11.0 10^9/L	0.3214	1.379	0.0055
Anemia	0.7432	2.103	0.0007
Arthritis	0.4749	1.608	0.0033
Asthma	0.4199	1.522	0.0004
Complex Fusion	0.3282	1.388	<0.0001
Coronary Artery Disease	0.3808	1.463	<0.0001
Drug-related Disorders	0.8358	2.307	0.0021
History of Stroke	0.5283	1.696	0.0007
History of Thrombosis and Embolism	0.6198	1.859	<0.0001
Mental Disorders	0.2609	1.298	0.0009
Morbid Obesity	0.6270	1.872	<0.0001
Paralysis and Palsy	0.8717	2.391	0.0003

* Odds ratios for “Age” and “Age Over 50” are calculated at units of 5. Using “Age Over 50” as an example, the risk for an in-hospital complication is about 20% higher for patients age 55 than for patients age 50.

APPENDICES

APPENDIX A: EXCLUSION DEFINITIONS

TABLE A1. CLINICAL COMPLEXITY EXCLUSIONS

Type of Exclusion	Diagnosis Code Any Position*	Code Description
Fracture – Malunion/Nonunion	733.81	Malunion of fracture
Fracture – Malunion/Nonunion	733.82	Nonunion of fracture
Fracture – Pathologic	733.10	Pathologic fracture, unspecified site
Fracture – Pathologic	733.13	Pathologic fracture of vertebrae
Fracture – Pathologic	733.19	Pathologic facture of other specified site
Fracture – Stress	733.95	Stress fracture of other bone
Fracture – Traumatic	805.00	Cervical fracture unspecified level without mention of spinal cord injury, closed
Fracture – Traumatic	805.01	C1 fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.02	C2 fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.03	C3 fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.04	C4 fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.05	C5 fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.06	C6 fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.07	C7 fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.08	Multiple cervical fractures without mention of spinal cord injury, closed
Fracture – Traumatic	805.10	Cervical fracture unspecified level without mention of spinal cord injury, open
Fracture – Traumatic	805.11	C1 fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.12	C2 fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.13	C3 fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.14	C4 fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.15	C5 fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.16	C6 fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.17	C7 fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.18	Multiple cervical fractures without mention of spinal cord injury, open
Fracture – Traumatic	805.2	Dorsal (thoracic) fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.3	Dorsal (thoracic) fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.4	Lumbar fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.5	Lumbar fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.6	Sacrum and coccyx fracture without mention of spinal cord injury, closed
Fracture – Traumatic	805.7	Sacrum and coccyx fracture without mention of spinal cord injury, open
Fracture – Traumatic	805.8	Unspecified fracture of vertebral column without mention of spinal cord injury, closed
Fracture – Traumatic	805.9	Unspecified fracture of vertebral column without mention of spinal cord injury, open
Fracture – Traumatic	806.00	C1-C4 level fracture with unspecified spinal cord injury, closed
Fracture – Traumatic	806.01	C1-C4 level fracture with complete lesion of cord, closed
Fracture – Traumatic	806.02	C1-C4 level fracture with anterior cord syndrome, closed
Fracture – Traumatic	806.03	C1-C4 level fracture with central cord syndrome, closed
Fracture – Traumatic	806.04	C1-C4 level fracture with other specified spinal cord injury, closed
Fracture – Traumatic	806.05	C5-C7 level fracture with unspecified spinal cord injury, closed
Fracture – Traumatic	806.06	C5-C7 level fracture with complete lesion of cord, closed
Fracture – Traumatic	806.07	C5-C7 level fracture with anterior cord syndrome, closed
Fracture – Traumatic	806.08	C5-C7 level fracture with central cord syndrome, closed

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

Type of Exclusion	Diagnosis Code Any Position*	Code Description
Fracture – Traumatic	806.09	C5-C7 level fracture with other specified spinal cord injury, closed
Fracture – Traumatic	806.10	C1-C4 level fracture with unspecified spinal cord injury, open
Fracture – Traumatic	806.11	C1-C4 level fracture with complete lesion of cord, open
Fracture – Traumatic	806.12	C1-C4 level fracture with anterior cord syndrome, open
Fracture – Traumatic	806.13	C1-C4 level fracture with central cord syndrome, open
Fracture – Traumatic	806.14	C1-C4 level fracture with other specified spinal cord injury, open
Fracture – Traumatic	806.15	C5-C7 level fracture with unspecified spinal cord injury, open
Fracture – Traumatic	806.16	C5-C7 level fracture with complete lesion of cord, open
Fracture – Traumatic	806.17	C5-C7 level fracture with anterior cord syndrome, open
Fracture – Traumatic	806.18	C5-C7 level fracture with central cord syndrome, open
Fracture – Traumatic	806.19	C5-C7 level fracture with other specified spinal cord injury, open
Fracture – Traumatic	806.20	T1-T6 level fracture with unspecified spinal cord injury, closed
Fracture – Traumatic	806.21	T1-T6 level fracture with complete lesion of cord, closed
Fracture – Traumatic	806.22	T1-T6 level fracture with anterior cord syndrome, closed
Fracture – Traumatic	806.23	T1-T6 level fracture with central cord syndrome, closed
Fracture – Traumatic	806.24	T1-T6 level fracture with other specified spinal cord injury, closed
Fracture – Traumatic	806.25	T7-T12 level fracture with unspecified spinal cord injury, closed
Fracture – Traumatic	806.26	T7-T12 level fracture with complete lesion of cord, closed
Fracture – Traumatic	806.27	T7-T12 level fracture with anterior cord syndrome, closed
Fracture – Traumatic	806.28	T7-T12 level fracture with central cord syndrome, closed
Fracture – Traumatic	806.29	T7-T12 level fracture with other specified spinal cord injury, closed
Fracture – Traumatic	806.30	T1-T6 level fracture with unspecified spinal cord injury, open
Fracture – Traumatic	806.31	T1-T6 level fracture with complete lesion of cord, open
Fracture – Traumatic	806.32	T1-T6 level fracture with anterior cord syndrome, open
Fracture – Traumatic	806.33	T1-T6 level fracture with central cord syndrome, open
Fracture – Traumatic	806.34	T1-T6 level fracture with other specified spinal cord injury, open
Fracture – Traumatic	806.35	T7-T12 level fracture with unspecified spinal cord injury, open
Fracture – Traumatic	806.36	T7-T12 level fracture with complete lesion of cord, open
Fracture – Traumatic	806.37	T7-T12 level fracture with anterior cord syndrome, open
Fracture – Traumatic	806.38	T7-T12 level fracture with central cord syndrome, open
Fracture – Traumatic	806.39	T7-T12 level fracture with other specified spinal cord injury, open
Fracture – Traumatic	806.4	Lumbar fracture with spinal cord injury, closed
Fracture – Traumatic	806.5	Lumbar fracture with spinal cord injury, open
Fracture – Traumatic	806.60	Sacrum and coccyx fracture with unspecified spinal cord injury, closed
Fracture – Traumatic	806.61	Sacrum and coccyx fracture with complete cauda equina lesion, closed
Fracture – Traumatic	806.62	Sacrum and coccyx fracture with other cauda equina injury, closed
Fracture – Traumatic	806.69	Sacrum and coccyx fracture with other spinal cord injury, closed
Fracture – Traumatic	806.70	Sacrum and coccyx fracture with unspecified spinal cord injury, open
Fracture – Traumatic	806.71	Sacrum and coccyx fracture with complete cauda equina lesion, open
Fracture – Traumatic	806.72	Sacrum and coccyx fracture with other cauda equina injury, open
Fracture – Traumatic	806.79	Sacrum and coccyx fracture with other spinal cord injury, open
Fracture – Traumatic	806.8	Unspecified fracture of vertebral column with spinal cord injury, closed
Fracture – Traumatic	806.9	Unspecified fracture of vertebral column with spinal cord injury, open

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

Type of Exclusion	Diagnosis Code Any Position*	Code Description
Mechanical Complication	996.40 (PDX)	Unspecified mechanical complication of internal orthopedic device, implant, and graft
Mechanical Complication	996.41 (PDX)	Mechanical loosening of prosthetic joint
Mechanical Complication	996.42 (PDX)	Dislocation of prosthetic joint
Mechanical Complication	996.43 (PDX)	Broken prosthetic joint implant
Mechanical Complication	996.44 (PDX)	Peri-prosthetic fracture around prosthetic joint
Mechanical Complication	996.45 (PDX)	Peri-prosthetic osteolysis
Mechanical Complication	996.46 (PDX)	Articular bearing surface wear of prosthetic joint
Mechanical Complication	996.47 (PDX)	Other mechanical complication of prosthetic joint implant
Mechanical Complication	996.49 (PDX)	Other mechanical complication of other internal orthopedic device, implant, and graft
Mechanical Complication	996.77 (PDX)	Other complications due to internal joint prosthesis
Mechanical Complication	996.78 (PDX)	Other complications due to other internal orthopedic device, implant, and graft
Malignant Neoplasms	170.2 (PDX)	Malignant neoplasm of vertebral column, excluding sacrum and coccyx
Malignant Neoplasms	170.3 (PDX)	Malignant neoplasm of ribs, sternum, and clavicle
Malignant Neoplasms	170.6 (PDX)	Malignant neoplasm of pelvic bones, sacrum, and coccyx
Malignant Neoplasms	170.9 (PDX)	Malignant neoplasm of bone and articular cartilage, site unspecified
Malignant Neoplasms	192.2 (PDX)	Malignant neoplasm of spinal cord
Malignant Neoplasms	198.3 (PDX)	Secondary malignant neoplasm of brain and spinal cord
Malignant Neoplasms	198.5 (PDX)	Secondary malignant neoplasm of bone and bone marrow
Malignant Neoplasms	199.0 (PDX)	Disseminated malignant neoplasm
Infection/Inflammation of Joint Traumatic	996.66 (PDX)	Infection and inflammatory reaction due to internal joint prosthesis
Infection/Inflammation of Joint Traumatic	996.67 (PDX)	Infection and inflammatory reaction due to other internal orthopedic device, implant, and graft

*Unless otherwise specified.

Type of Exclusion	Procedure Code Any Position	Code Description
Refusion	81.30	Refusion of spine, not otherwise specified
Refusion	81.31	Refusion of atlas-axis spine
Refusion	81.32	Refusion of other cervical spine, anterior column, anterior technique
Refusion	81.33	Refusion of other cervical spine, posterior column, posterior technique
Refusion	81.34	Refusion of dorsal and dorsolumbar spine, anterior column, anterior technique
Refusion	81.35	Refusion of dorsal and dorsolumbar spine, posterior column, posterior technique
Refusion	81.36	Refusion of lumbar and lumbosacral spine, anterior column, anterior technique
Refusion	81.37	Refusion of lumbar and lumbosacral spine, posterior column, posterior technique
Refusion	81.38	Refusion of lumbar and lumbosacral spine, anterior column, posterior technique
Refusion	81.39	Refusion of spine, not elsewhere classified
Removal Device/Prosthesis*	78.69	Removal of implanted device from bone, other specified sites
Removal Device/Prosthesis*	80.09	Arthrotomy for removal of prosthesis without replacement, other specified site

*Excluded when the removal of the device is prior to or on the date of the first spinal fusion in the hospitalization.

APPENDIX A: EXCLUSION DEFINITIONS *(CONTINUED)*

TABLE A2. MS-DRG CRITERIA FOR ELECTIVE SPINAL FUSION SURGERY STUDY POPULATION DEFINITION

MS-DRGs *Not* Excluded from the Study	
MS-DRG 453	Combined Anterior/Posterior Spinal Fusion with MCC
MS-DRG 454	Combined Anterior/Posterior Spinal Fusion with CC
MS-DRG 455	Combined Anterior/Posterior Spinal Fusion without CC/MCC
MS-DRG 456	Spinal Fusion Except Cervical with Spinal Curvature/Malignancy/Infection or 9+ Fusions with MCC
MS-DRG 457	Spinal Fusion Except Cervical with Spinal Curvature/Malignancy/Infection or 9+ Fusions with CC
MS-DRG 458	Spinal Fusion Except Cervical with Spinal Curvature/Malignancy/Infection or 9+ Fusions without CC/MCC
MS-DRG 459	Spinal Fusion Except Cervical with MCC
MS-DRG 460	Spinal Fusion Except Cervical 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 471	Cervical Spinal Fusion with MCC
MS-DRG 472	Cervical Spinal Fusion with CC
MS-DRG 473	Cervical Spinal Fusion without CC/MCC

APPENDIX B: COMPLICATION DEFINITION

Complication	ICD-9-CM Diagnosis Code	Description
Surgical Site Bleeding [1]	998.11	Hemorrhage complicating a procedure
	998.12	Hematoma complicating a procedure
Wound Complication [1]	349.0	Reaction to spinal or lumbar puncture
	349.31	Accidental puncture or laceration of dura during a procedure
	349.39	Other dural tear
	997.01	Central nervous system complication
	998.13	Seroma complicating a procedure
	998.30	Disruption of wound, unspecified
	998.31	Disruption of internal operation (surgical) wound
	998.32	Disruption of external operation (surgical) wound
	998.51	Infected postoperative seroma
	998.59	Other postoperative infection
	998.6	Persistent postoperative fistula
	998.83	Non-healing surgical wound
Infection of Device, Implant, and Graft [2]	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
Mechanical Complication of Device, Implant, and Graft [2]	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
	996.47	Other mechanical complication of prosthetic joint implant
	996.49	Other mechanical complication of other internal orthopedic device, implant, and graft

[1] This complication is counted as a readmission for a complication when the readmission is within 30 days of the hospitalization during which the spinal fusion was performed.

[2] This complication is counted as a readmission for a complication when the readmission is within 90 days of the hospitalization during which the spinal fusion was performed.

APPENDIX C: DEFINITIONS OF ICD-9-CM CODE-BASED POTENTIAL RISK FACTORS

Potential Risk Factor	**ICD-9-CM Codes** (in any diagnosis/procedure position unless noted otherwise)
Acquired Deformity of Knee and Hip Joint	736.30, 736.31, 736.32, 736.39, 736.41, 736.42, 736.5, 736.6, 736.81
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	696.0, 711.05, 711.06, 711.08, 711.95, 711.96, 711.98, 714.0, 714.1, 714.2, 714.30, 714.31, 714.32, 714.33, 714.4, 714.89, 714.9, 730.08, 730.15, 730.16, 730.18, 730.28, 720.0 The following code with a Present on Admission indicator of Yes (Y) or Clinically Undetermined (W): 324.1
Arthropathy of Joints	094.0, 274.00, 274.01, 274.02, 274.03, 713.5, 716.08, 716.15, 716.16, 716.18, 716.55, 716.56, 716.58, 716.59, 716.65, 716.66, 716.68, 716.85, 716.86, 716.88, 716.95, 716.96, 716.98, 718.48, 718.55, 718.56, 718.58, 718.85, 718.86, 718.88, 718.95, 718.98
Aseptic Necrosis	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	The following codes with a Present on Admission indicator of Yes (Y) or Clinically Undetermined (W): 427.31, 427.32
Cancer	140.0-209.36, 209.70-209.79, 230.0-239.9
Cardiomyopathy	402.00, 402.10, 402.90, 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, 442.81
Chronic DVT of Lower Extremities	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	135, 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
Complex Fusion	At least one of the following scenarios: Cervical fusion • Isolated level; posterior approach only – procedure code 81.03 without 81.01 or 81.02 • Isolated level; multiple approach – procedure combinations of ONLY TWO of the following procedure codes: 81.01, 81.02, 81.03 Dorsal Fusion • Isolated level; multiple approach – BOTH procedure codes 81.04 and 81.05 Lumbar Fusion • Isolated level; anterior approach only – procedure code 81.06 without 81.07 or 81.08 • Isolated level; multiple approach – procedure combinations of ONLY TWO of the following procedure codes: 81.06, 81.07, 81.08 Multiple Fusion • Cervical and dorsal – at least one of 81.01, 81.02, 81.03 AND at least one of 81.04, 81.05 • Dorsal and lumbar – at least one of 81.04, 81.05 AND at least one of 81.06, 81.07, 81.08 • Cervical and lumbar – at least one of 81.01, 81.02, 81.03 AND at least one of 81.06, 81.07, 81.08

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

Potential Risk Factor	**ICD-9-CM Codes** (in any diagnosis/procedure position unless noted otherwise)
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
Congenital Musculoskeletal Deformity	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
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 Spine	723.5, 737.0, 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, 738.2, 738.3, 738.5, 739.0, 739.1, 739.2, 739.3, 739.4, 754.2, 756.10, 756.13, 756.14, 756.15, 756.16, 756.19
Dementia and Cerebral Degeneration	330.0, 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
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
Dislocation of Vertebrae	The following codes with a Present on Admission indicator of Yes (Y) or Clinically Undetermined (W): 718.28, 718.38, 839.00, 839.01, 839.02, 839.03, 839.04, 839.05, 839.06, 839.07, 839.08, 839.20, 839.21, 839.40, 839.41, 839.42, 839.49
Drug-related Disorders	292.0, 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, The following codes with a Present on Admission indicator of Yes (Y) or Clinically Undetermined (W): 292.11, 292.12, 292.2, 292.81, 292.82, 292.83, 292.84, 292.85, 292.89, 292.9
Electrolyte Imbalance	The following codes with a Present on Admission indicator of Yes (Y) or Clinically Undetermined (W): 276.0, 276.1, 276.2, 276.3, 276.4, 276.7, 276.8
Environmental and Economic Factors	V60.0, V60.1, V60.2, V60.3, V60.4
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 Disorders	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

APPENDIX C: DEFINITIONS OF 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 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
History of Coronary and Valve Procedures	V42.2, V43.3, V45.81, V45.82
History of Defibrillator or Pacemaker	V45.01, V45.02, V53.31, V53.32, V53.39
History of Knee and Hip Joint Replacement	V43.64, V43.65
History of Long-term Anticoagulant Use	V58.61, V58.63
History of Long-term Insulin Use	V58.67
History of Long-term Oxygen Use	V46.2
History of Long-term Steroid Use	V58.65
History of Lower Extremity Amputation	V49.70, V49.71, V49.72, V49.73, V49.74, V49.75, V49.76, V49.77
History of Non-Compliance with Medical Treatment	V15.81, V45.12
History of Spinal Fusion	V45.4
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	401.0, 401.1, 401.9, 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 spinal fusion: 00.18, 33.50, 33.51, 33.52, 33.6, 37.51, 37.52, 37.53, 41.00, 41.02, 41.03, 41.05, 41.06, 41.08, 41.94, 46.97, 50.51, 50.59, 52.80, 52.81, 52.82, 52.83, 52.85, 52.86, 55.69
Joint, Muscle, and Ligament Disorders	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
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
Lower Extremity Ulcer – Chronic	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, 309.1, 309.81, 311
Morbid Obesity	278.01, V85.39, V85.41, V85.42, V85.43, V85.44, V85.45
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

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

Potential Risk Factor	**ICD-9-CM Codes** (in any diagnosis/procedure position unless noted otherwise)
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	278.03, 327.23
Osteopathy	730.70, 731.0, 731.1, 731.3, 731.8, 732.1, 732.4, 732.7, 732.8, 732.9
Osteoporosis	733.00, 733.01, 733.02, 733.03, 733.09
Other Inflammatory Spondylopathies	720.1, 720.2, 720.81, 720.89, 720.9, 721.5, 721.6, 721.7, 721.8
Paralysis and Palsy	138, 343.0, 343.1, 343.2, 343.3, 343.4, 343.8, 343.9 The following codes with a Present on Admission indicator of Yes (Y) or Clinically Undetermined (W): 342.00, 342.01, 342.02, 342.10, 342.11, 342.12, 342.80, 342.81, 342.82, 342.90, 342.91, 342.92, 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, 344.60, 344.61, 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
Postlaminectomy Syndrome	The following codes with a Present on Admission indicator of Yes (Y) or Clinically Undetermined (W): 722.80, 722.81, 722.82, 722.83
Spinal Stenosis without Spondylolisthesis	723.0, 724.00, 724.01, 724.02, 724.03, 724.09 without diagnosis code 738.4, 756.11, or 756.12
Spondylolisthesis	738.4, 756.11, 756.12
Spondylosis	721.0, 721.1, 721.2, 721.3, 721.41, 721.42, 721.90, 721.91
Thyroid Disorders	240.9, 241.0, 241.1, 241.9, 242.00, 242.01, 242.10, 242.11, 242.20, 242.21, 242.30, 242.31, 242.40, 242.41, 242.80, 242.81, 242.90, 242.91, 243, 244.0, 244.1, 244.2, 244.3, 244.8, 244.9, 245.2, 245.3, 245.4, 245.8, 245.9
Tobacco Use	305.1
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 D: EXAMPLE OF LOGISTIC REGRESSION

Calculations Used in Determining Expected In-Hospital Complication Rates for a Given Hospital

Spinal Fusion

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

Actual Percent In-Hospital Complication: Total number of cases with in-hospital complication / total number of hospitalizations.

Expected Percent In-Hospital Complication: Mean of the predicted probability of in-hospital complication for each hospitalization.

Step 1: Calculate the predicted probability of in-hospital complication for each hospitalization (PInComplication):

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

$$= -0.6661 + (-0.1371)\,(\text{Age}) + 0.1669\,(\text{Age Over 30}) + \ldots + 0.4278\,(\text{WBC} \geq 11.0\ 10^9\text{L}) + \ldots + 0.5201\,(\text{Spondyloisthesis})$$

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

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

where $e \approx 2.7182818285$

Step 2: Calculate the mean probability of in-hospital complication (PInComplication) for each hospital (expected percent of in-hospital complication)

$$\text{PInComplication} = \frac{\Sigma\ \text{PInComplication}}{n}$$

APPENDIX D: EXAMPLE OF CASE-MIX ADJUSTMENT

Western PA
Spinal Fusion

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.

Western PA (Region 1, 2, 3) and MS-DRG 453: $315,378
or
Western PA (Region 1, 2, 3) and MS-DRG 454: $260,161
or
Other PA Region/MS-DRG combination

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

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

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