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A Comparison of DRG and CPT for Cost Analysis in Spine Surgery

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A thesis submitted to the Faculty of the
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Abstract

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The prevalence of neck and back disorders in the United States is estimated to be 80% in the adult population and represents the third largest source of spending, totaling $87.6 Billion USD. The most common grouping of administrative healthcare data is by Diagnosis Related Group (DRG), but in spine surgery the array of pathologies, operations, and techniques contained in a single DRG is very heterogeneous. Current Procedure Terminology (CPT) codes focus on reimbursement for services rendered and can be more specific to describe the surgical approach and technique performed. The specificity and familiarity of the CPT coding structure for surgeons makes it an attractive option for classification in spine surgery cost analysis research. We conducted a retrospective cohort study of 5,020 surgeries over 4 years at a single institution aimed at comparing the association between total cost and either MS-DRG or our novel CPT-based surgical categorization method (CSC). The adjusted R^2 for a linear regression model of total cost was similar for MS-DRG and CSC (0.65 vs. 0.57) and the addition of the CSC term to the MS-DRG model had a significant increase in the R^2 (0.65 to 0.74). To allow for cost analysis at the surgical or provider level, the CSC method creates groups of similar surgical approaches and techniques, enabling better analysis of the drivers of variability that could predict changes in total cost. Further development of this CSC method may enable the development of surgeon-led initiatives to streamline resource utilization and maximize procedural cost savings in spine surgery.

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INTRODUCTION

Rising costs threaten the sustainability of health care in the United States. The prevalence of neck and back disorders is estimated to be 80% in the adult population, and not only are spine conditions common, but they also encompass a large proportion of total US health care. (1) These neck and back care expenditures have increased 6.5% percent since 1996, and now represent the third largest source of spending, totaling $87.6 Billion USD, trailing only diabetes and heart disease. (2) Recent scrutiny from insurance companies as well as the US government has led many administrators, medical directors, and practitioners to try and investigate the reasons for these costs. Why are neck and back conditions so expensive? Is there something specific about the pathophysiology that results in such high costs, or is it related to the prevalence of the disease? Rather, could there be factors related to patterns of care and decisions made by physicians that contribute to the high costs? To answer these questions, one first must be able to accurately summarize the costs of neck and back care and to be able to track factors related to both the patient and the practitioners that might be contributing to the expense of the care provided. The purpose of our project was to investigate the relationship between commonly used billing codes and the total cost of spine surgical care to better utilize administrative and billing databases in cost analysis research. We hypothesized that a Current Procedure Terminology (CPT) code based surgical categorization model will better predict total cost in Spine Surgery when compared with a Diagnosis Related Group (DRG) based model.

BACKGROUND

The ability to accurately compare and analyze cost variability depends on a classification method that encompasses the relevant treatment decisions in the plan of care. In spine surgery, a single type of pathology could require one of several different surgical approaches and/or techniques, all with varying cost and resource utilization. While cost accounting would seem to be a simple task, large variability in patient-specific factors, geographic practice patterns, facility-specific costs, and provider preferences introduces significant complexity into cost analysis procedures. (3-5) Centers for Medicare and Medicaid (CMS) have been trying to reduce the variability of healthcare costs, with recent emphasis on bundled-care payment agreements. The first such agreement was for cardiovascular surgery in 1984, and more recently the Medicare Access and CHIP Reauthorization Act of 2015 (MACRA) has mandated increases in value-based health care delivery with bundled spine surgery programs soon expected. (6, 7)

One of the primary difficulties in costs analysis research is the method used to summarize and categorize the costs of care. Hospital reimbursement and bundled-payment totals are based on Diagnosis Related Groups (DRGs), which are a set of 3-digit codes developed by Fetter and Thompson at Yale, and have been used since 1982 to classify the expected reimbursement for a particular diagnosis or procedure performed. (8) Each patient encounter is assigned an International Classification of Disease (ICD) code(s) and is then grouped according to expected hospital resource utilization due to factors like procedures performed, patient-specific comorbidities, and complications to a particular DRG. (9) While the most common grouping of administrative healthcare data is by DRG, in spine surgery the array of pathologies, operations, and techniques lumped into a single DRG is very heterogeneous. This inherent heterogeneity in spine DRGs impedes easy identification of variations and opportunities for standardization of outliers.

Unlike DRGs, the method used by surgeons to classify the type of service performed is Current Procedural Terminology (CPT) coding. CPT codes are a set of 5-digit codes developed and copyright protected by the American Medical Association (AMA) that focus on reimbursement for services rendered or procedures performed by physicians, instead of the diagnosis and expected resource utilization in DRGs. (10) CPT codes can be more specific, and a set of codes can be used in series to describe the various details of a procedure or service performed. Due to the ability to combine CPT codes, the combinations of codes increase in a linear relationship with the complexity of the procedure or service performed. While the primary purpose for CPT codes is to map to a Relative Value Unit (RVU) of care to guide professional fee compensation for physicians, the specificity and familiarity of the coding structure makes it an attractive option for classification and analysis of the costs of medical care. Moreover, it can provide specificity as to the type of variability in the care provided by a physician. For instance, within a certain set of DRG, multiple CPTs are considered standard of care for a particular ailment but each CPT combination has different financial implications.

Others have attempted to use CPTs for health services research in spine diseases. Wang et al. took an important first step toward including the specificity of CPT codes into a categorization algorithm. They utilized a combined CPT and ICD-9 categorization method to predict the type of surgical procedure employed for 332 patients undergoing cervical spine surgery. The purpose of this algorithm was to use administrative claims data, which lacks the detailed information regarding type of surgical procedure and number of levels treated, to sub-categorized predicted surgical treatments and enable detailed cost analysis within the cohort. They demonstrate impressive sensitivity and specificity for degenerative pathologies, but this effect is lost with increasing numbers of levels treated and procedures in the thoracic and lumbar spine. (11)

Due to the large number of patients and the lack of a need for IRB approval, large administrative databases such as the Nationwide Inpatient Sample (NIS) and the National Surgical Quality

Improvement Program (NSQIP) have been utilized for health services research within spine surgery. The presence of patient level factors, complications and comorbidities, and the total costs of care within the database enable multivariate analyses that can be used to draw powerful conclusions about causes for cost variability in spine surgery. These databases, however, are not always as reliable as they may seem. First, most cost data are reported by MS-DRG and is tied to hospital billing and reimbursement schemes without surgeon-specific or provider-specific billing data. Second, there are significant questions about the accuracy of not only the billing data, but also the clinical factors contained within these databases. In several investigations, observed rates of spinal deformity surgeries were much higher than those reported in the literature, and there were several common complications that were not observed or reported at all within the databases. (12, 13) As a result, the strength of the conclusions derived from administrative database research projects are dependent on not only the quality of the data, but also the method used to analyze the costs associated with the surgical treatments.

While DRGs may capture inpatient costs related to particular types of pathology, there does not exist a spine-surgery specific classification method to analyze a surgical procedure and its expected costs. The inherent heterogeneity contained as well as the correlation with hospital costs and reimbursements could prevent the reliable use of MS-DRGs for cost analysis research in spine surgery. Thus, there is a need for a spine-surgery-specific method for cost analysis based on CPT codes, the most familiar, specific, and useful coding method used by spine surgeons.

METHODS

Hypothesis and Specific Aims

We hypothesized that a Current Procedure Terminology (CPT) code-based model will better predict total cost in spine surgery when compared with a Diagnosis Related Group (DRG) based model. To test this hypothesis, we aimed to 1.) estimate the association between the Diagnosis Related Group and the total cost of a spinal surgical procedure among all patients undergoing spine surgical procedures in the Emory healthcare system; 2.) estimate the association between the Current Procedural Terminology code(s) and the total cost of a spinal surgical procedure among all patients undergoing spine surgical procedures in the Emory healthcare system; and 3.) compare the ability of DRG and CPT code categories to predict total cost in Spine Surgery.

Study Design and Study Population

The study was a retrospective cohort study from a single institution and was approved by the Institutional Review Board. The study period was from December 2011 to August 2016, which represents Fiscal Years 2012–2016. The study population included all patients undergoing a spine surgical procedure within the Emory healthcare system, consisting of a tertiary care academic hospital, a specialty orthopedics and spine-only hospital, and a hybrid academic/private practice hospital. The surgeons performing the spine surgeries included both neurosurgeons and orthopedic surgeons, with residents, fellows, and affiliate care providers serving as first assistant. Patients included in the study population were greater than 18 years old with any diagnosis requiring a spine surgical procedure who underwent an inpatient spine surgery. Patients also were included only if their records included completed hospital cost data as well as provider billing data from the inpatient admission and surgical procedure. Patients were excluded if they underwent outpatient or same-day spine surgical procedures, as well as if they underwent multiple operations during the same hospital stay.

Deidentified patient data from the Emory electronic medical record (Cerner PowerChart, North Kansas City, Missouri) were merged with financial accounting data from the Emory Healthcare EPSi cost accounting system (Allscripts Inc., Chicago, Illinois) using a financial encounter code as the linking variable. These data represent the hospital billing data for each financial encounter. Each observation was then filtered by MS-DRG to select only those encounters that were for a spine surgical procedure. For a list of MS-DRG codes used to filter the encounters, see Figure 1. Each financial linking variable from the accounting software was used to query the Emory site-specific surgical database (Cerner SurgiNet, North Kansas City, Missouri) to obtain all relevant CPT-codes for each encounter. These data represent the professional billing data entered by each surgeon for each surgical procedure. For a list of all included CPT codes, see Figure 2. Data collected included the patient financial encounter code, dates of admission and discharge, MS-DRG category, all CPT codes from the surgical billing data, Total Cost in USD, and Total Direct Cost in USD.

CPT-based Surgical Categorization Method

A novel CPT-based surgical categorization method was created *a priori* for this analysis. Each surgery was categorized based on spine region (cervical, thoracic, and lumbar) and assigned a numeric value of “1”, “2”, or “3”. Then, the subtype category was assigned based on the type of operation (anterior fusion, posterior fusion, anterior/posterior fusion, or posterior non-fusion) using “A”, “B”, “C”, or “D”. Finally, a modifier is assigned to designate number of levels fused (“i”, “ii”, or “iii” when “A”, “B”, or “C”) or type of posterior, non-fusion procedure (“i”, “ii”, or “iii” when “D”). As an example, an anterior, cervical, single-level fusion would be categorized as “1Ai” whereas a posterior, lumbar, non-fusion with a discectomy would be categorized as "3Diii". For a full description of the categories and modifiers, see Figure 3. The categorization of each spine surgery is based on the combination of CPT codes entered for each procedure by the surgeon. Each category is defined by a combination of codes which are additive and only represent the minimum of codes needed to differentiate individual case types. As a result, each case may have more than the minimum number of codes, but the unique combination of key codes is what differentiates individual case types. The key assumption for the categorization method is that the categories are independent of indications, which enables broad generalizability and applicability to all subspecialties of spine surgery, such as degenerative, tumor, and deformity.

Data Analysis

The hospital billing data and the professional billing data were imported into R (version 3.3.1, R Foundation for Statistical Computing, Vienna, Austria) using the *readxl* package. (14, 15) The professional billing data was transformed into a matrix using the *dplyr* package and a new variable for each CPT code was created. (16) Filtering logic and the *mutate* function were the used to create each individual CPT category. For more details regarding the steps required to create the CPT categories, please see the Supplemental Resources for each step with associated code in R. Once the CPT category variable was created, the CPT data was merged with the hospital billing data using the financial encounter as the linking variable. Encounters with procedures in more than one region (defined as multiple CPT categories for each encounter) or that had outpatient surgery (defined as length of stay equal to zero days) were excluded. The outcome measure for analysis was total hospital cost at the individual encounter level. Total hospital costs represent the sum of all costs to the facility related to the specific patient inpatient visit and does not include surgeon and physician professional fees. Examples of costs included in total hospital costs are OR supplies, surgical implants, ICU costs, floor room stay, medical/surgical supplies, pharmaceuticals, imaging, radiology, and laboratories as well as the cost distributed to the encounter to compensate for hospital overhead. Hospital costs were extracted from the hospital chargemaster, which included charge descriptions, billing codes, and hospital costs according to cost center. Total cost was selected as the outcome variable to allow for a global inclusion of all potential costs related to each patient encounter. The predictor variables were indicator variables for DRG and/or CPT categories. This would allow for maximum generalizability not only for different types of spine surgical procedures but also different inpatient settings within our healthcare system.

First, an outlier analysis was performed using Total Direct Cost in USD, with surgery excluded if they included any extreme or illogical values for Total Direct Cost. Next, descriptive statistics were generated for relevant DRG categories as well as each CPT-procedure category using the *dplyr* package in R, and box-plots were created using the *ggplot2* package. (16, 17) Descriptive statistics calculated included frequency, mean, median, standard deviation, median, and coefficient of variation by DRG and CPT category. Next, the dataset was split into training and validation subsets, with 70% used for training and 30% used for model validation. Linear regression modeling was performed using the ordinary least squares (*ols*) function in the *rms* package. (18) The coefficient of determination (R^2) of the linear regression model (Total Cost ~ CPT category) was used to indicate the ability of CPT categories to account for variation in total cost within the dataset. Further comparison of the models was performed using the Akaike Information Criteria (AIC) and the Bayesian Information Criteria (BIC). The model derived from the training set was then used to calculate predicted total cost for each MS-DRG and CSC, and the correlation between predicted and actual total cost was then calculated. The threshold for statistical significance was set at an α of 0.05

RESULTS

There were 16 MS-DRGs included in the analysis (Figure 1) and 26 distinct CPT codes included for analysis (Figure 2). There were 9,033 encounters within the dataset during the study period; 1,939 encounters were not complete and were excluded, leaving 7,095 complete encounters in the dataset (Figure 3). Of the encounters, 1,978 contained duplicate regions or CPT surgical categories, and were excluded, leaving 5,117 unique encounters within the dataset. Outlier analysis identified 97 records with extreme or illogical cost data and were excluded, leaving 5,020 encounters for analysis. Total cost was plotted which revealed a skewed, non-normal distribution (Figure 5). Thus, a logarithmic transformation was performed which resulted in a more normal distribution, better for use in our model (Figure 6). Graphical analysis of total cost versus MS-DRG and total cost versus CSC was performed using boxplots (Figure 7 and 8). Notably, there was a trend of increasing median total cost from subcategory A to B to C, with a decrease in the median total cost in the non-fusion category of D consistent across cervical, thoracic, and lumbar regions.

There were 5,020 surgical procedures in 16 separate MS-DRG categories, but notably 3,343 were from MS-DRG 460, 473, and 491 which represents 66.5% of the total cases from only 18.8% of the categories. The median total cost was \$22,320 with an IQR of \$17,225. The largest median total cost was MS-DRG 456 with a median total cost of \$64,105 (IQR \$30,600, n=33). The smallest median total cost was MS-DRG 491 at \$10,205 (IQR \$5,070, n=667) (Table 1). Of the 5,020 surgical procedures in the dataset, there were a total of 17,640 separate CPT codes in 29 different categories (Table 2). Each operation contained 3-4 CPT codes, with the most frequently represented CPTs including 22612/22614, 22840/22842, 22851, and 63047/63048.

When using our CSCs, there were 30 distinct CSCs within the 5,020 surgeries in the dataset, as seen in Table 3. 1,433 cervical operations were represented by 8 separate CSCs, representing

28.5% of the total operations (Table 4). The median total cost for cervical region surgeries was $15,624 (IQR $9,219). Anterior fusions (1Ai and 1Aii) represent 56% of all cervical operations, with a median total cost of $13,084 - $18,788 (IQR $4,405 - $6,062). The most expensive cervical operation was an anterior/posterior cervical fusion (1Civ) with a median total cost of $37,054 (IQR $17,273).

There were 358 thoracic operations represented by 11 separate CSCs, representing 7.1% of the total operations (Table 5). The median total cost for thoracic region surgeries was $32,778 (IQR $27,430). Posterior fusions (2Bi – 2Biv) represent 56.1% of thoracic operations, with median total cost of $19,610 - $6,7261 (IQR $7,235 - $19,230). The most expensive thoracic surgery was a 7-12 level posterior fusion (2Biv) with a median total cost of $67,261 (IQR $19,230).

There were 3,229 lumbar operations represented by 11 separate CSCs, representing 64.3% of the total operations (Table 6). The median total cost for lumbar operations was $24,451 (IQR $16,171). Posterior fusion operations (3Bi – 3Biv) represent 47.6% of all lumbar operations, with a median total cost of $24,695 - $66,255 (IQR ($6,518 - $15,884). Posterior decompression/non-fusion operations represent 36.2% of all lumbar operations, with a median total cost of $9,377 - $11,796 (IQR $5,194 - $11,666).

There were 3,266 fusions operations are represented by 24 CSCs, which represents 65.1% of the total operations in the dataset (Table 7). The median total cost for a fusion operation was $25,390 (IQR $15,272). There were 1,754 non-fusion operations are represented by 6 CSCs, which represents 34.9% of the total operations in the dataset (Table 8). The median total cost for a non-fusion operation was $14,024 (IQR $13056).

In preparation for linear regression modeling, the dataset was subdivided into a training dataset and a validation training set. The 70% used for the training set resulted in 3,512 operations, with the remaining 30% accounting for 1,508 operations within the validation set. The training set was then used to estimate the association between Log Total Cost and MS-DRG using the following model: log(TOTALCOST)= $\beta_0 + \sum_{i=1}^{n} \beta_i *$ MS-DRG$_i$. β_0 represents the estimated log total cost of the reference group, which is MS-DRG 453, n is the number of DRGs, and each of the MS-DRGs is a dummy variable with β_i representing the estimated difference of the log total cost for the tested MS-DRG when compared to the log total cost of the reference group. All but two of the coefficients were statistically significant, and the training model yielded an adjusted R^2 of 0.6545 with an F-statistic of 444.6 on 15 and 4,496 degrees of freedom ($p<0.001$). The validation model performed similarly, with an adjusted R^2 of 0.6189 with an F-statistic of 175.8 on 14 and 1,493 degrees of freedom ($p<0.001$) (Tables 9 and 10).

The training set was then used to estimate the association between log total cost and our CSC groups using the following model: log(TOTALCOST)= $\beta_0 + \sum_{i=1}^{n} \beta_i *$ CSC$_i$. β_0 represents the estimated log total cost of the reference group, which is CSC 1Ai, n is the number of CSCs, and each of the CSCs is a dummy variable with β_i representing the estimated difference of the log total cost for the tested CSC when compared to the log total cost of the reference group. All but one of the coefficients were statistically significant and the training model yielded an adjusted R^2 of 0.5709 with an F-statistic of 162.1 on 29 and 3,482 degrees of freedom ($p<0.001$). The validation model performed similarly with all but two predictors achieving statistical significance, with an adjusted R^2 of 0.5353 and an F-statistic of 70.43 on 25 and 1,482 degrees of freedom ($p<0.001$) (Table 11 and 12).

Lastly, the training set was then used to estimate the association between log total cost and both MS-DRG and CSC groups using the following model: log(TOTALCOST)=β_0 + $\sum_{i=1}^{n} \beta_i *$

$\text{MS-DRG}_i + \sum_{j=1}^{n} \beta_j * \text{CSC}_j$. All but 4 of the coefficients were statistically significant, and the training model yielded an adjusted R^2 of 0.744. The validation model performed similarly with an adjusted R^2 of 0.708 (Table 13 and 14). Next, an analysis of variance was performed comparing the combined model with the MS-DRG only model, which showed that the addition of the CSC term to the model was statistically significant. Using the coefficients from the training model, estimated total costs were then predicted and compared to the actual total costs. The MS-DRG only model demonstrated a correlation of 0.784 while the CSC only model demonstrated a correlation of 0.728. The combined MS-DRG and CSC model demonstrated a correlation of 0.836 (Table 15).

DISCUSSION

Within our cohort of 5,020 patients, we observed an R^2 of 0.65 when modeling the association between total cost and MS-DRG and an R^2 of 0.57 when modeling the association between total cost and our CPT-based surgical categorization method. As a result, we reject our hypothesis that CPT will better predict total cost when compared to DRG in spine surgery. While the R^2 for CSC and total cost was similar but less than that for MS-DRG, the addition of the CSC term to the MS-DRG model showed a statistically significant increase in the R^2 (0.65 to 0.74) as well as an increase in the correlation between predicted and actual total cost (0.78 to 0.84). While the R^2 was lower, our results confirm that DRGs contain patient level information that CPTs (and in turn, the CSC) do not.

Despite the lower R^2, the advantages of using a CPT-based surgical categorization method are best demonstrated graphically in Figures 6 and 7. There exists significant cost variability in several overrepresented categories and the inherent heterogeneity within each MS-DRG make it difficult to understand what is being compared between groups. The CSC method, however, enables better basic understanding of what is being compared between each group, and also helps the reader to visualize the surgical approaches and techniques that are contained in each group. For example, when comparing groups with number 1 (cervical), number 2 (thoracic), and number 3 (lumbar) CSCs there is a recurring trend of increasing total cost from groups with letter A (anterior approach for fusion), letter B (posterior approach for fusion), and letter C (combined anterior/posterior approach for fusion), with a predictable and consistent drop in total cost for groups with letter D (posterior approach for non-fusion). This same trend is identified when increasing the number of levels treated (indicated with i, ii, iii, iv, etc.).

Further proof of the value of a CPT-based surgical categorization method is contained in Figures 4 – 8. The straightforward logic of the CSC method allows for powerful comparison of different surgical approaches in different regions of the spine, as well as comparison of fusion vs. non-fusion techniques. For example, it is difficult to understand why the median cost of care for MS-DRG 456 is $64,105 when compared to the median cost of $10,205 for MS-DRG 491. Yet, the comparison of median total cost for operations by spinal region (cervical $15,624, thoracic $32,778, lumbar $24,451) or technique (fusion $25,390, non-fusion $14,024) can be easily and instantly appreciated. As asked previously, why are neck and back conditions so expensive? Is there something specific about the disease process or pathophysiology that results in such high costs, or is it solely related to the prevalence of the disease? Through the use of the CPT-based surgical categorization method, we can better categorize and summarize the costs of care for similar surgical approaches and techniques which in turn will allow for better analysis of the factors that result in variability within homogenous groups.

The CPT-based surgical categorization method is a novel addition not only for spine surgery, but also for possible applications to other surgical specialties in the future. As shown previously, the utility of MS-DRGs for health services research and cost analysis projects is limited due to reclassification of MS-DRGs. MS-DRGs 490 and 491 were eliminated by CMS in 2014 and replaced by MS-DRGs 518-520. Even as specific CPT codes may change, the filtering logic and classification algorithm can be updated and amended as necessary to ensure consistent and lasting classification of surgical approaches and technique and prevent the loss of data for analysis due to obsolescence of the classification system. While our project supports the use of CSCs alone for cost analysis, the most significant result is the strength of combining both MS-DRG and CSCs for cost analysis, which results in a correlation of over 80% of predicted and actual total costs. These data suggest that future cost analysis projects must include our CSC to better standardize comparison of like spine surgical approaches and techniques.

One of the strength of our analysis results from the size and makeup of our dataset. This project represents the largest spine surgical cost analysis project in the literature that is not based on the Nationwide Inpatient Sample (NIS) or the National Surgical Quality Improvement Program (NSQIP), both of which have been shown to have significant questions regarding the accuracy and reliability of the data within the datasets. Further, our dataset is composed of procedures performed at a mix of hospital types (academic, private practice, "privademic", and spine-specific surgery hospital) and by both neurosurgeons and orthopaedic surgeons, which greatly increases the generalizability to other institutions. Lastly, our rigorous methods and use of a training and validation dataset for our model shows that the use of our CSC in a linear regression model can be expected to likely perform well on data from similar settings. This is advantageous not only for future cost analysis projects at the institutional level, but also for the use of validated databases and registries (such as the National Neurosurgery Quality Outcomes Database) in coming years.

Despite these advantages, our project is not without limitations. Even with the heterogeneous makeup of our dataset with representation from multiple hospital settings and surgeons from both disciplines, our study is retrospective and from a single center. Even with multiple years of data included, we had a very large number of excluded encounters (>4000) due to missing data. Additionally, there were several MS-DRGs as well as CSCs that were underrepresented, which limits the conclusions that can be drawn from analysis for those particular groups. Lastly, our dataset was from an administrative database originally created for billing and reimbursement purposes and not expressly for research.

In the future, the development of this CPT-based categorization method will enable the development of surgeon-led initiatives to streamline resource utilization and maximize procedural cost savings. At our institution, we are nearing the completion of a two-year, surgeon-initiated pilot project aimed at value acceleration through practice standardization for spine surgical procedures and diagnoses. This method allows for surgical procedure specific analysis of cost variability, which would not be possible with the administrative billing data alone. Furthermore, the use of our CSC method will enable integration of billing data with future clinical case series and cohort studies. The inclusion of cost data can allow for the integration of traditional clinical outcome measures (radiographic measurements, patient reported outcomes, complication rates, etc.) with cost effectiveness calculations, and could serve to establish a new gold standard for value-based spine surgical research.

CONCLUSIONS

Why are neck and back conditions so expensive? Through our novel, CPT-based surgical categorization method, surgeons and administrators will be able to better answer this question by more accurately measuring and accounting for the specific costs of care related to particular surgical approaches and techniques than DRG-only approaches. This surgical procedure focused method will enable future health services research into the root causes for cost variability in spine surgery.

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TABLES AND FIGURES

Figure 1: Spine Related MS-DRG Codes

MS-DRG	DESCRIPTION
453	Combined anterior and posterior spinal fusion (with major complication or comorbidity)
454	Combined anterior and posterior spinal fusion (with complication or comorbidity)
455	Combined anterior and posterior spinal fusion (without complication or comorbidity or major complication or comorbidity)
456	Spinal fusion (except cervical) with spinal curvature, malignancy, or infection or 9+ levels of fusion (with major complication or comorbidity)
457	Spinal fusion (except cervical) with spinal curvature, malignancy, or infection or 9+ levels of fusion (with complication or comorbidity)
458	Spinal fusion (except cervical) with spinal curvature, malignancy, or infection or 9+ levels of fusion (without complication or comorbidity or major complication or comorbidity)
459	Spinal fusion (except cervical, with major complication or comorbidity)
460	Spinal fusion (except cervical, without major complication or comorbidity)
471	Cervical spinal fusion (with major complication or comorbidity)
472	Cervical spinal fusion (with complication or comorbidity)
473	Cervical spinal fusion (without complication or comorbidity or major complication or comorbidity)
490	Back and neck procedures, including disc device and/or neurostimulator, (except spinal fusion) with complication or comorbidity or major complication or comorbidity
491	Back and neck procedures, including disc device and/or neurostimulator, (except spinal fusion) without complication or comorbidity or major complication or comorbidity
518	Back and neck procedures, including disc device and/or neurostimulator, (except spinal fusion) with major complication or comorbidity
519	Back and neck procedures, including disc device and/or neurostimulator, (except spinal fusion) with complication or comorbidity
520	Back and neck procedures, including disc device and/or neurostimulator, (except spinal fusion) without complication or comorbidity or major complication or comorbidity

Figure 2: Spine Related CPT Codes

CPT	DESCRIPTION
22551	Arthrodesis, anterior interbody, including disc space preparation, discectomy, osteophytectomy and decompression of spinal cord and/or nerve roots; cervical below C2
22552	Arthrodesis, anterior interbody, including disc space preparation, discectomy, osteophytectomy and decompression of spinal cord and/or nerve roots; cervical below C2, each additional interspace (List separately in addition to code for separate procedure)
22554	Arthrodesis, anterior interbody technique, including minimal discectomy to prepare interspace (other than for decompression); cervical below C2
22556	Arthrodesis, anterior interbody technique, including minimal discectomy to prepare interspace (other than for decompression); thoracic
22558	Arthrodesis, anterior interbody technique, including minimal discectomy to prepare interspace (other than for decompression); lumbar
22585	Arthrodesis, anterior interbody technique, including minimal discectomy to prepare interspace (other than for decompression); each additional interspace (List separately in addition to code for primary procedure)
22595	Arthrodesis, posterior technique, atlas-axis (C1-C2)
22600	Arthrodesis, posterior or posterolateral technique, single level; cervical below C2 segment
22610	Arthrodesis, posterior or posterolateral technique, single level; thoracic (with lateral transverse technique, when performed)
22612	Arthrodesis, posterior or posterolateral technique, single level; lumbar (with lateral transverse technique, when performed)
22614	Arthrodesis, posterior or posterolateral technique, single level; each additional vertebral segment (List separately in addition to code for primary procedure)
22633	Arthrodesis, combined posterior or posterolateral technique with posterior interbody technique including laminectomy and/or discectomy sufficient to prepare interspace (other than for decompression), single interspace and segment; lumbar
22634	Arthrodesis, combined posterior or posterolateral technique with posterior interbody technique including laminectomy and/or discectomy sufficient to prepare interspace (other than for decompression), single interspace and segment; each additional interspace and segment (List separately in addition to code for primary procedure)
22840	Posterior non-segmental instrumentation (e.g., Harrington rod technique, pedicle fixation across 1 interspace, atlantoaxial transarticular screw fixation, sublaminar wiring at C1, facet screw fixation) (List separately in addition to code for primary procedure)
22842	Posterior segmental instrumentation (e.g., pedicle fixation, dual rods with multiple hooks and sublaminar wires); 3 to 6 vertebral segments (List separately in addition to code for primary procedure)
22843	Posterior segmental instrumentation (e.g., pedicle fixation, dual rods with multiple hooks and sublaminar wires); 7 to 12 vertebral segments (List separately in addition to code for primary procedure)
22844	Posterior segmental instrumentation (e.g., pedicle fixation, dual rods with multiple hooks and sublaminar wires); 13 or more vertebral segments (List separately in addition to code for primary procedure)

22845	Anterior instrumentation; 2 to 3 vertebral segments (List separately in addition to code for primary procedure)
22846	Anterior instrumentation; 4 to 7 vertebral segments (List separately in addition to code for primary procedure)
22851	Application of intervertebral biomechanical device(s) (e.g., synthetic cage(s), methyl methacrylate) to vertebral defect or interspace (List separately in addition to code for primary procedure)
63001	Laminectomy with exploration and/or decompression of spinal cord and/or cauda equina, without facetectomy, foraminotomy or discectomy (e.g., spinal stenosis), 1 or 2 vertebral segments; cervical
63003	Laminectomy with exploration and/or decompression of spinal cord and/or cauda equina, without facetectomy, foraminotomy or discectomy (e.g., spinal stenosis), 1 or 2 vertebral segments; thoracic
63015	Laminectomy with exploration and/or decompression of spinal cord and/or cauda equina, without facetectomy, foraminotomy or discectomy (e.g., spinal stenosis), more than 2 vertebral segments; cervical
63016	Laminectomy with exploration and/or decompression of spinal cord and/or cauda equina, without facetectomy, foraminotomy or discectomy (e.g., spinal stenosis), more than 2 vertebral segments; thoracic
63030	Laminotomy (hemilaminectomy), with decompression of nerve root(s), including partial facetectomy, foraminotomy and/or excision of herniated intervertebral disc; 1 interspace, lumbar
63045	Laminectomy, facetectomy and foraminotomy (unilateral or bilateral with decompression of spinal cord, cauda equina and/or nerve root[s], [e.g., spinal or lateral recess stenosis]), single vertebral segment; cervical
63047	Laminectomy, facetectomy and foraminotomy (unilateral or bilateral with decompression of spinal cord, cauda equina and/or nerve root[s], [e.g., spinal or lateral recess stenosis]), single vertebral segment; lumbar
63048	Laminectomy, facetectomy and foraminotomy (unilateral or bilateral with decompression of spinal cord, cauda equina and/or nerve root[s], [e.g., spinal or lateral recess stenosis]), single vertebral segment; each additional segment, cervical, thoracic, or lumbar (List separately in addition to code for primary procedure)
63051	Laminoplasty, cervical, with decompression of the spinal cord, 2 or more vertebral segments; with reconstruction of the posterior bony elements (including the application of bridging bone graft and non-segmental fixation devices [e.g., wire, suture, mini-plates], when performed)

Figure 3: CPT Categorization Method

Procedure Labeling Method	
Number: Spinal Region	
1	Cervical
2	Thoracic
3	Lumbar
Letter: Relative Location	
A	Anterior Fusion
B	Posterior Fusion
C	Anterior/Posterior Fusion
D	Posterior Non-Fusion
Roman numerals: Number of Segments, or a procedure type	
i., ii.,iii., iv. (when A-C)	Increasing numbers of segments
i., ii.,iii. (when D)	i: Non-instrumented or laminoplasty ii. Laminectomy, or with foraminotomy iii. Discectomy or laminectomy

Figure 4: Flowchart of Inclusion/Exclusion Process

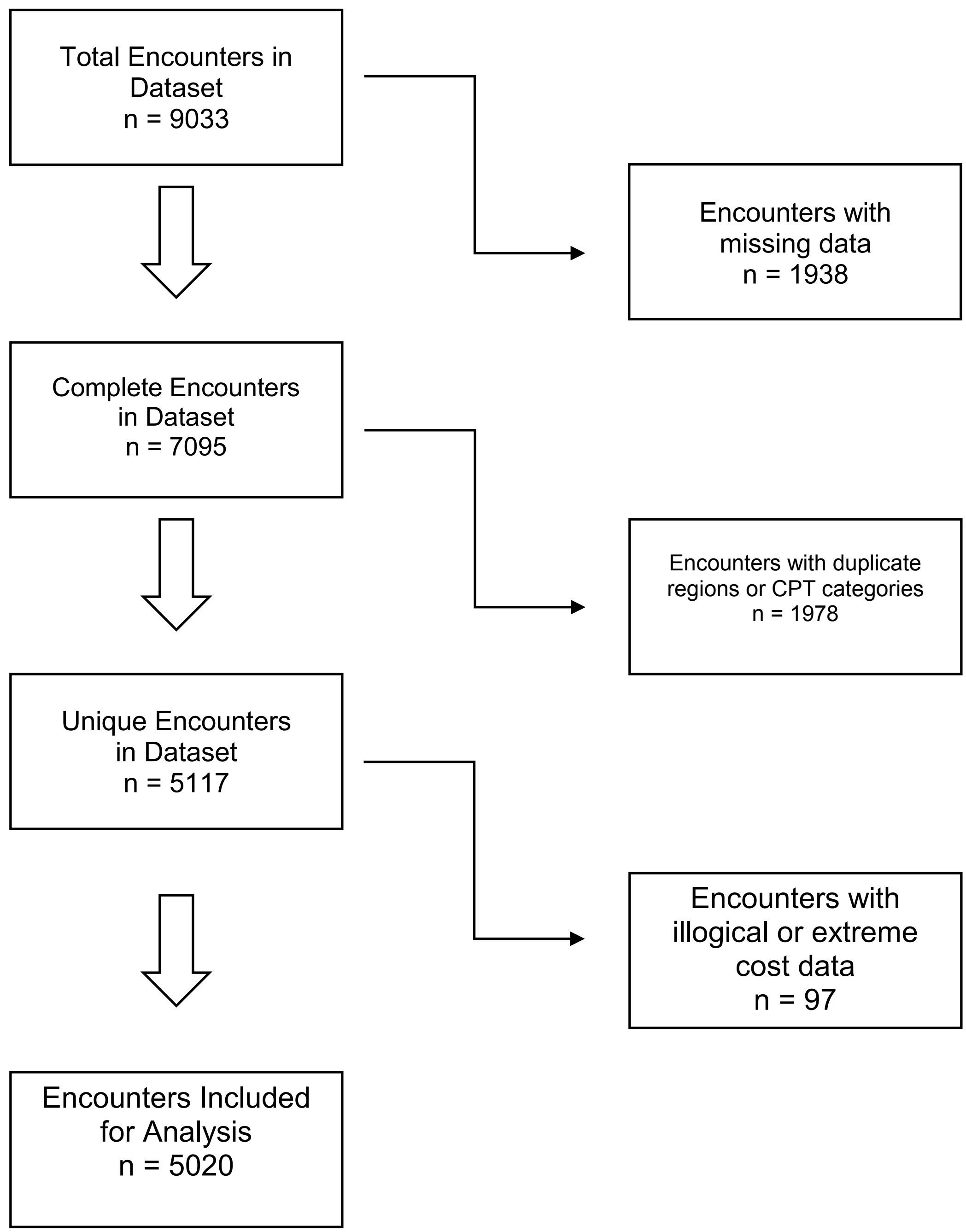

Figure 5: Distribution of Total Cost

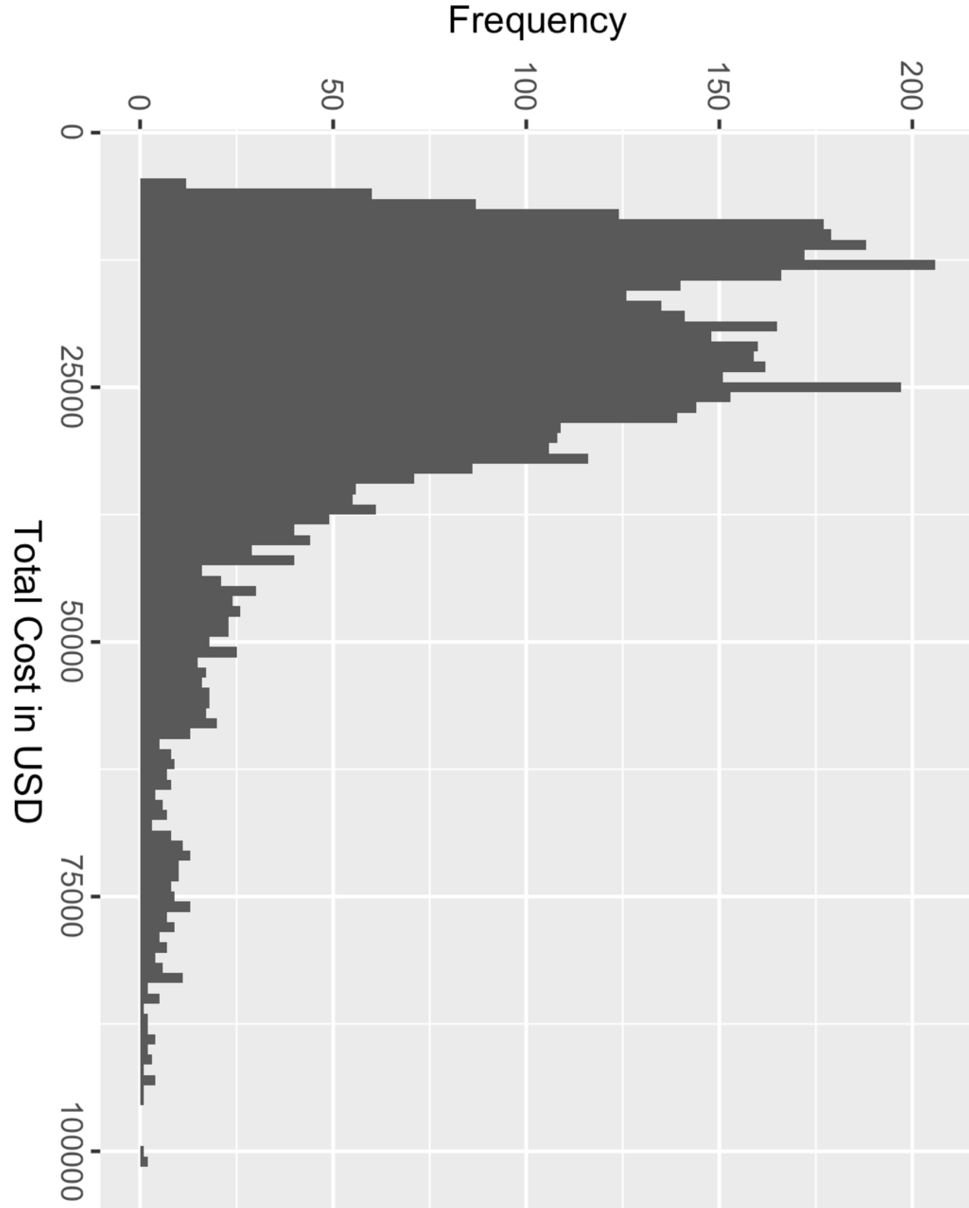

Figure 6: Distribution of Logarithm of Total Cost

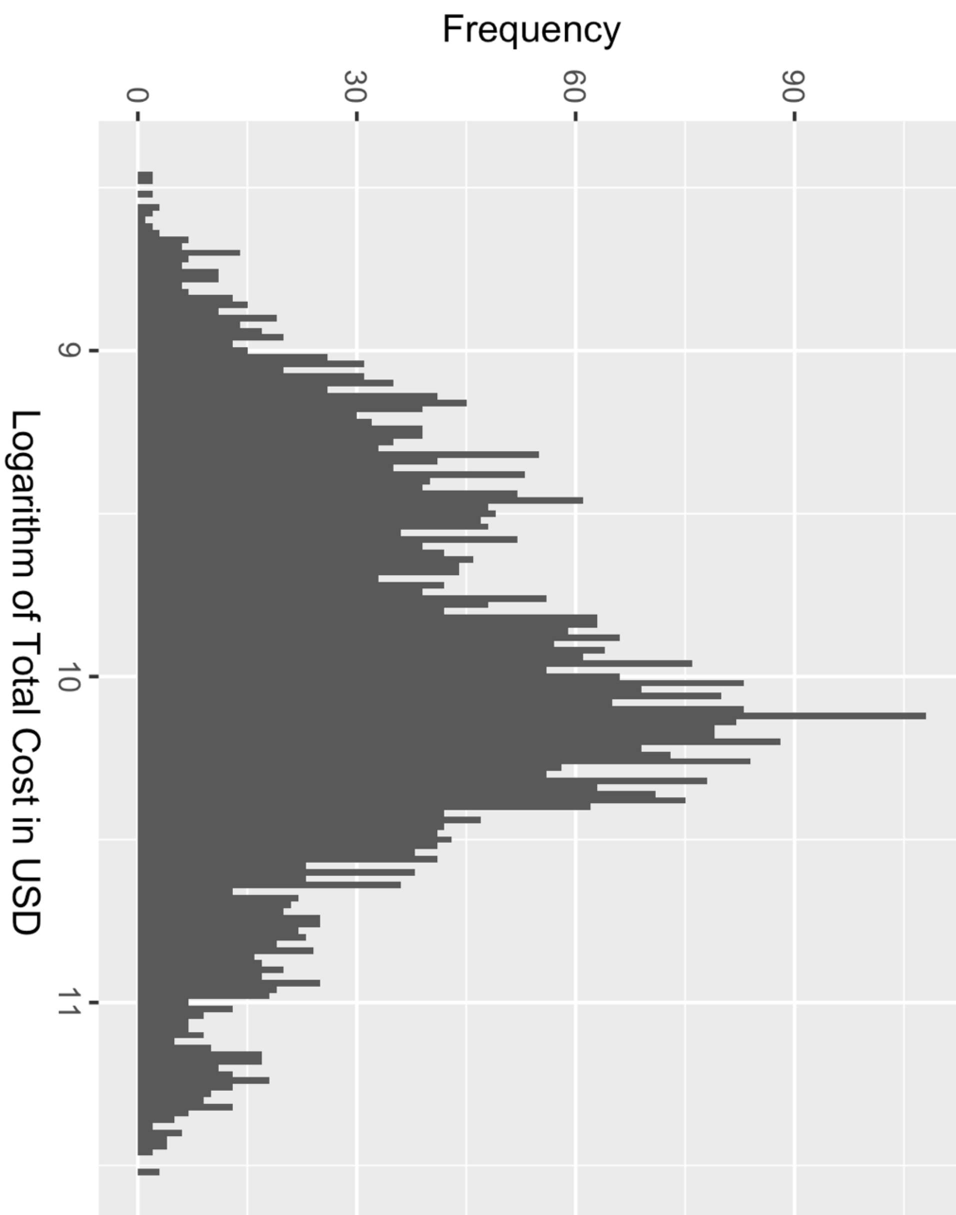

Figure 7: Boxplot of DRG Category and Total Cost

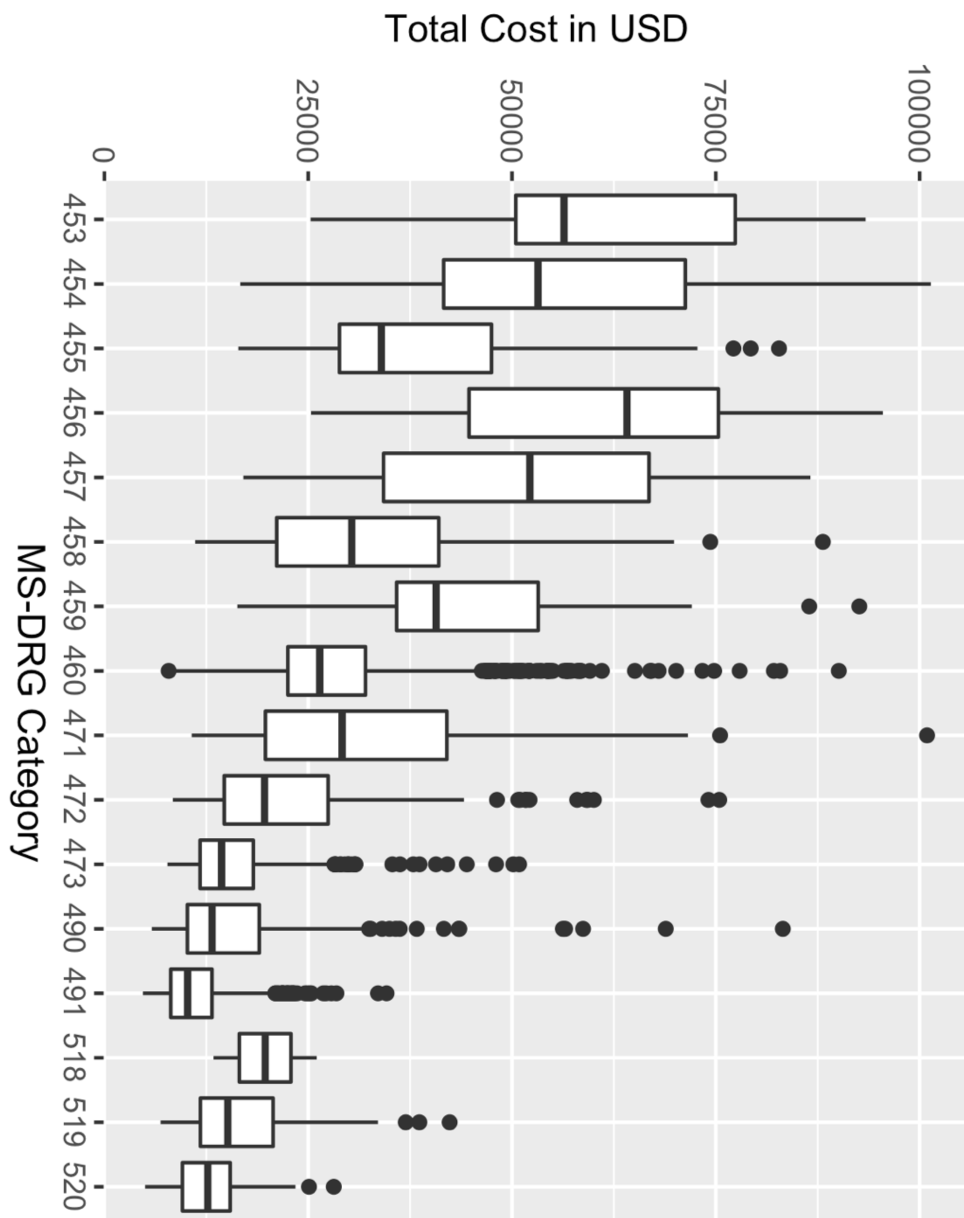

Figure 8: Boxplot of CPT Based Surgical Categories and Total Cost

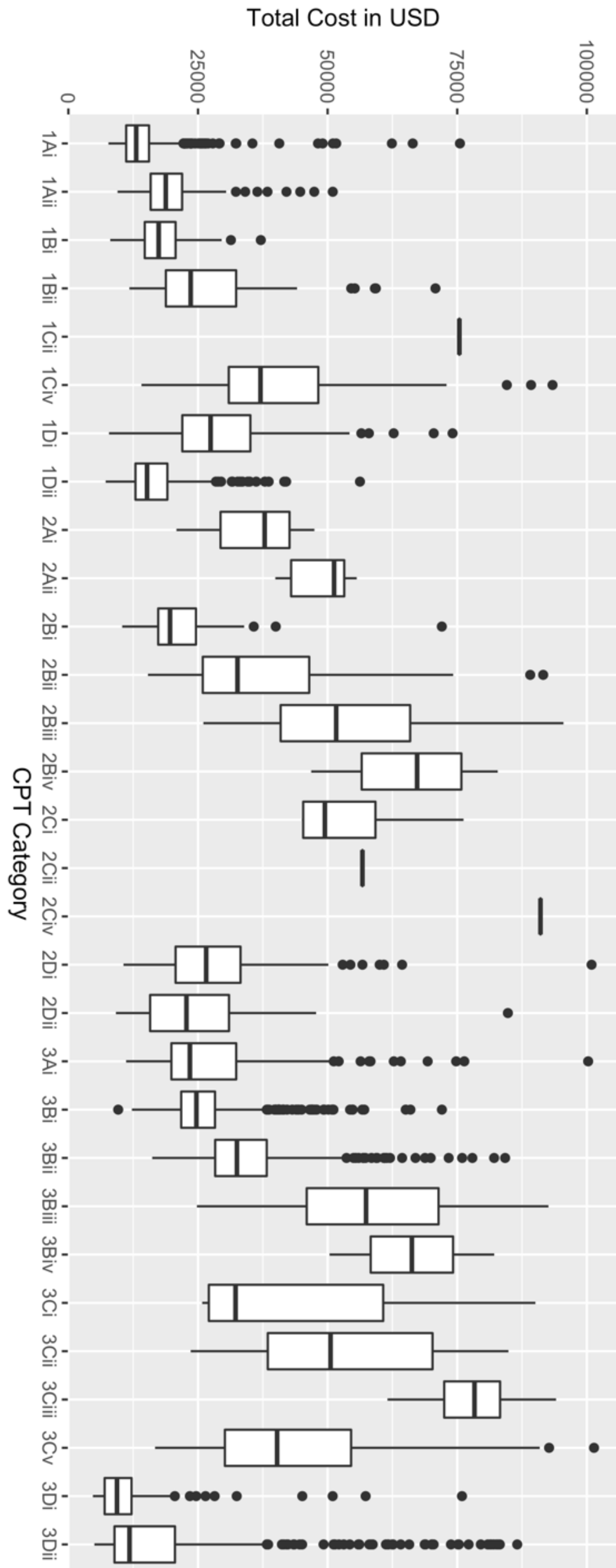

Table 1: Descriptive Statistics for MS-DRG Codes

MS-DRG	n	Median Total Cost	IQR	Mean Total Cost	Standard Deviation	Coefficient of Variation
453	32	56385	26914	61974	17711	28.6
454	218	53184	29642	55706	18240	32.7
455	107	33976	18650	38813	13882	35.8
456	33	64105	30600	61033	18761	30.7
457	173	52194	32571	51454	18556	36.1
458	99	30338	19884	32856	14677	44.7
459	53	40692	17365	45371	15861	35.0
460	1967	26422	9518	28114	8663	30.8
471	63	29162	22254	33890	18670	55.1
472	301	19642	12747	22330	10758	48.2
473	709	14367	6536	15737	5879	37.4
490	310	13203	8812	16140	9630	59.7
491	667	10205	5070	11288	4533	40.2
518	2	19720	6332	19720	8954	45.4
519	98	15134	8916	17000	7395	43.5
520	188	12685	5860	12909	4123	31.9
16	5020	22320	17225	25265	15580	61.7

Table 2: Frequency of CPT Codes in Dataset

CPT Code	Frequency
22551	757
22552	436
22554	141
22556	19
22558	526
22585	337
22595	44
22600	401
22610	284
22612	1111
22614	1260
22633	884
22634	112
22840	1183
22842	1103
22843	329
22844	27
22845	707
22846	220
22851	1917
63001	278
63003	37
63015	150
63016	22
63030	130
63045	146
63047	2491
63048	2250
63051	338
29	17640

Table 3: Descriptive Statistics for CPT Based Surgical Categories

CSC	n	Median Total Cost	IQR	Mean Total Cost	Standard Deviation	Coefficient of Variation
1Ai	614	13084	4405	14412	6341	44.0
1Aii	183	18788	6062	19796	6331	32.0
1Bi	40	17422	5942	18146	5642	31.1
1Bii	40	23592	13548	28458	14237	50.0
1Cii	1	75414	0	75414	NA	NA
1Civ	114	37054	17273	40639	14284	35.1
1Di	110	27432	13128	30476	12436	40.8
1Dii	331	15176	6161	16709	6068	36.3
2Ai	3	37857	13307	35386	13478	38.1
2Aii	5	51250	10251	48593	6795	14.0
2Bi	24	19610	7279	23335	12726	54.5
2Bii	80	32624	20528	38527	17710	46.0
2Biii	79	51657	24984	53703	16539	30.8
2Biv	18	67261	19230	66052	11813	17.9
2Ci	4	49471	13938	55052	14653	26.6
2Cii	1	56716	0	56716	NA	NA
2Civ	1	91060	0	91060	NA	NA
2Di	124	26580	12530	29391	12628	43.0
2Dii	19	22776	15216	26129	17000	65.1
3Ai	242	23442	12496	27745	11898	42.9
3Bi	958	24695	6518	25804	6682	25.9
3Bii	538	32510	9942	34325	9617	28.0
3Biii	39	57420	25436	59669	15970	26.8
3Biv	2	66255	15884	66255	22463	33.9
3Ci	12	32245	33636	45682	25988	56.9
3Cii	39	50574	31774	52896	17255	32.6
3Ciii	24	78335	10774	78533	8325	10.6
3Cv	205	40261	24344	45003	18249	40.6
3Di	105	9377	5194	12165	10646	87.5
3Dii	1065	11796	11666	16537	12781	77.3
30	5020	22320	17225	25265	15580	61.7

Table 4: Descriptive Statistics for Cervical CPT Based Surgical Categories

CSC	n	Median Total Cost	IQR	Mean Total Cost	Standard Deviation	Coefficient of Variation
1Ai	614	13084	4405	14412	6341	44.0
1Aii	183	18788	6062	19796	6331	32.0
1Bi	40	17422	5942	18146	5642	31.1
1Bii	40	23592	13548	28458	14237	50.0
1Cii	1	75414	0	75414	NA	NA
1Civ	114	37054	17273	40639	14284	35.1
1Di	110	27432	13128	30476	12436	40.8
1Dii	331	15176	6161	16709	6068	36.3
8	1433	15624	9219	19488	11281	57.9

Table 5: Descriptive Statistics for Thoracic CPT Based Surgical Categories

CSC	n	Median Total Cost	IQR	Mean Total Cost	Standard Deviation	Coefficient of Variation
2Ai	3	37857	13307	35386	13478	38.1
2Aii	5	51250	10251	48593	6795	14.0
2Bi	24	19610	7279	23335	12726	54.5
2Bii	80	32624	20528	38527	17710	46.0
2Biii	79	51657	24984	53703	16539	30.8
2Biv	18	67261	19230	66052	11813	17.9
2Ci	4	49471	13938	55052	14653	26.6
2Cii	1	56716	0	56716	NA	NA
2Civ	1	91060	0	91060	NA	NA
2Di	124	26580	12530	29391	12628	43.0
2Dii	19	22776	15216	26129	17000	65.1
11	358	32778	27430	38916	19340	49.7

Table 6: Descriptive Statistics for Lumbar CPT Based Surgical Categories

CSC	n	Median Total Cost	IQR	Mean Total Cost	Standard Deviation	Coefficient of Variation
3Ai	242	23442	12496	27745	11898	42.9
3Bi	958	24695	6518	25804	6682	25.9
3Bii	538	32510	9942	34325	9617	28.0
3Biii	39	57420	25436	59669	15970	26.8
3Biv	2	66255	15884	66255	22463	33.9
3Ci	12	32245	33636	45682	25988	56.9
3Cii	39	50574	31774	52896	17255	32.6
3Ciii	24	78335	10774	78533	8325	10.6
3Cv	205	40261	24344	45003	18249	40.6
3Di	105	9377	5194	12165	10646	87.5
3Dii	1065	11796	11666	16537	12781	77.3
11	3229	24451	16171	26315	15588	59.2

Table 7: Descriptive Statistics for Fusion Operations

CSC	n	Median Total Cost	IQR	Mean Total Cost	Standard Deviation	Coefficient of Variation
1Ai	614	13084	4405	14412	6341	44.0
1Aii	183	18788	6062	19796	6331	32.0
1Bi	40	17422	5942	18146	5642	31.1
1Bii	40	23592	13548	28458	14237	50.0
1Cii	1	75414	0	75414	NA	NA
1Civ	114	37054	17273	40639	14284	35.1
2Ai	3	37857	13307	35386	13478	38.1
2Aii	5	51250	10251	48593	6795	14.0
2Bi	24	19610	7279	23335	12726	54.5
2Bii	80	32624	20528	38527	17710	46.0
2Biii	79	51657	24984	53703	16539	30.8
2Biv	18	67261	19230	66052	11813	17.9
2Ci	4	49471	13938	55052	14653	26.6
2Cii	1	56716	0	56716	NA	NA
2Civ	1	91060	0	91060	NA	NA
3Ai	242	23442	12496	27745	11898	42.9
3Bi	958	24695	6518	25804	6682	25.9
3Bii	538	32510	9942	34325	9617	28.0
3Biii	39	57420	25436	59669	15970	26.8
3Biv	2	66255	15884	66255	22463	33.9
3Ci	12	32245	33636	45682	25988	56.9
3Cii	39	50574	31774	52896	17255	32.6
3Ciii	24	78335	10774	78533	8325	10.6
3Cv	205	40261	24344	45003	18249	40.6
24	3266	25390	15272	29062	15685	54.0

Table 8: Descriptive Statistics for Non-Fusion Operations

CSC	n	Median Total Cost	IQR	Mean Total Cost	Standard Deviation	Coefficient of Variation
1Di	110	27432	13128	30476	12436	40.8
1Dii	331	15176	6161	16709	6068	36.3
2Di	124	26580	12530	29391	12628	43.0
2Dii	19	22776	15216	26129	17000	65.1
3Di	105	9377	5194	12165	10646	87.5
3Dii	1065	11796	11666	16537	12781	77.3
6	1754	14024	13056	18195	12644	69.5

Table 9: Linear Regression Parameters of Log Total Cost vs. DRG

MS-DRG	Coefficient	2.5% CI	97.5% CI	p-value
Intercept	10.979	10.845	11.11	<0.001
454	-0.081	-0.225	0.06	0.269
455	-0.469	-0.624	-0.31	<0.001
456	0.057	-0.132	0.25	0.554
457	-0.183	-0.330	-0.04	0.014
458	-0.710	-0.866	-0.55	<0.001
459	-0.306	-0.475	-0.14	<0.001
460	-0.779	-0.914	-0.64	<0.001
471	-0.689	-0.859	-0.52	<0.001
472	-1.086	-1.228	-0.94	<0.001
473	-1.374	-1.512	-1.24	<0.001
490	-1.442	-1.583	-1.30	<0.001
491	-1.703	-1.841	-1.57	<0.001
518	-1.144	-1.636	-0.65	<0.001
519	-1.335	-1.492	-1.18	<0.001
520	-1.553	-1.700	-1.41	<0.001

Table 10: Exponentiated Linear Regression Parameters of Log Total Cost vs. DRG

MS-DRG	Coefficient	2.5% CI	97.5% CI	p-value
Intercept	58652.22	51301.09	67056.71	<0.001
454	0.92	0.80	1.06	0.269
455	0.63	0.54	0.73	<0.001
456	1.06	0.88	1.28	0.554
457	0.83	0.72	0.96	0.014
458	0.49	0.42	0.57	<0.001
459	0.74	0.62	0.87	<0.001
460	0.46	0.40	0.53	<0.001
471	0.50	0.42	0.59	<0.001
472	0.34	0.29	0.39	<0.001
473	0.25	0.22	0.29	<0.001
490	0.24	0.21	0.27	<0.001
491	0.18	0.16	0.21	<0.001
518	0.32	0.19	0.52	<0.001
519	0.26	0.22	0.31	<0.001
520	0.21	0.18	0.24	<0.001

Table 11: Linear Regression Parameters of Log Total Cost vs. CPT Based Surgical Category

CSC	Coefficient	2.5% CI	97.5% CI	p-value
(Intercept)	9.528	9.492	9.56	<0.001
1Aii	0.315	0.239	0.39	<0.001
1Bi	0.166	0.022	0.31	0.023
1Bii	0.699	0.533	0.87	<0.001
1Cii	1.702	0.955	2.45	<0.001
1Civ	1.071	0.979	1.16	<0.001
1Di	0.702	0.602	0.80	<0.001
1Dii	0.167	0.107	0.23	<0.001
2Ai	1.126	0.597	1.66	<0.001
2Aii	1.239	0.864	1.61	<0.001
2Bi	0.387	0.207	0.57	<0.001
2Bii	0.879	0.766	0.99	<0.001
2Biii	1.345	1.242	1.45	<0.001
2Biv	1.554	1.358	1.75	<0.001
2Ci	1.537	1.008	2.07	<0.001
2Cii	1.417	0.670	2.16	<0.001
2Civ	1.891	1.144	2.64	<0.001
2Di	0.707	0.620	0.80	<0.001
2Dii	0.500	0.272	0.73	<0.001
3Ai	0.633	0.565	0.70	<0.001
3Bi	0.596	0.550	0.64	<0.001
3Bii	0.885	0.833	0.94	<0.001
3Biii	1.427	1.284	1.57	<0.001
3Biv	1.543	1.014	2.07	<0.001
3Ci	0.966	0.715	1.22	<0.001
3Cii	1.283	1.142	1.42	<0.001
3Ciii	1.756	1.580	1.93	<0.001
3Cv	1.123	1.051	1.19	<0.001
3Di	-0.275	-0.372	-0.18	<0.001
3Dii	-0.019	-0.064	0.03	0.424

Table 12: Exponentiated Linear Regression Parameters of Log Total Cost vs. CPT Based Surgical Category

CSC	Coefficient	2.5% CI	97.5% CI	p-value
(Intercept)	13745.08	13253.55	14254.83	<0.001
1Aii	1.37	1.27	1.48	<0.001
1Bi	1.18	1.02	1.36	0.023
1Bii	2.01	1.70	2.38	<0.001
1Cii	5.49	2.60	11.58	<0.001
1Civ	2.92	2.66	3.20	<0.001
1Di	2.02	1.83	2.23	<0.001
1Dii	1.18	1.11	1.26	<0.001
2Ai	3.08	1.82	5.23	<0.001
2Aii	3.45	2.37	5.02	<0.001
2Bi	1.47	1.23	1.76	<0.001
2Bii	2.41	2.15	2.70	<0.001
2Biii	3.84	3.46	4.25	<0.001
2Biv	4.73	3.89	5.76	<0.001
2Ci	4.65	2.74	7.89	<0.001
2Cii	4.13	1.95	8.71	<0.001
2Civ	6.62	3.14	13.99	<0.001
2Di	2.03	1.86	2.22	<0.001
2Dii	1.65	1.31	2.07	<0.001
3Ai	1.88	1.76	2.02	<0.001
3Bi	1.81	1.73	1.90	<0.001
3Bii	2.42	2.30	2.55	<0.001
3Biii	4.17	3.61	4.81	<0.001
3Biv	4.68	2.76	7.94	<0.001
3Ci	2.63	2.04	3.38	<0.001
3Cii	3.61	3.13	4.16	<0.001
3Ciii	5.79	4.86	6.89	<0.001
3Cv	3.07	2.86	3.30	<0.001
3Di	0.76	0.69	0.84	<0.001
3Dii	0.98	0.94	1.03	0.424

Table 13: Linear Regression Parameters of Log Total Cost vs. DRG plus CPT Based Surgical Category

Parameter	Coefficient	2.5% CI	97.5% CI	p-value
(Intercept)	10.388	10.245	10.53	<0.001
454	-0.075	-0.204	0.05	0.257
455	-0.396	-0.537	-0.26	<0.001
456	-0.005	-0.182	0.17	0.955
457	-0.245	-0.386	-0.10	0.001
458	-0.652	-0.800	-0.50	<0.001
459	-0.191	-0.347	-0.04	0.016
460	-0.610	-0.741	-0.48	<0.001
471	-0.376	-0.540	-0.21	<0.001
472	-0.753	-0.896	-0.61	<0.001
473	-0.919	-1.061	-0.78	<0.001
490	-1.301	-1.441	-1.16	<0.001
491	-1.585	-1.723	-1.45	<0.001
518	-1.132	-1.562	-0.70	<0.001
519	-1.230	-1.383	-1.08	<0.001
520	-1.517	-1.662	-1.37	<0.001
1Aii	0.289	0.230	0.35	<0.001
1Bi	0.172	0.062	0.28	0.002
1Bii	0.540	0.408	0.67	<0.001
1Cii	1.595	1.017	2.17	<0.001
1Civ	0.592	0.498	0.69	<0.001
1Di	0.623	0.542	0.70	<0.001
1Dii	0.778	0.687	0.87	<0.001
2Ai	0.391	-0.029	0.81	0.068
2Aii	0.734	0.433	1.03	<0.001
2Bi	0.070	-0.087	0.23	0.381
2Bii	0.479	0.365	0.59	<0.001
2Biii	0.837	0.726	0.95	<0.001
2Biv	0.951	0.775	1.13	<0.001
2Ci	0.714	0.293	1.13	0.001
2Cii	1.168	0.586	1.75	<0.001
2Civ	1.031	0.437	1.63	0.001
2Di	0.535	0.461	0.61	<0.001
2Dii	0.621	0.430	0.81	<0.001

3Ai	0.355	0.264	0.45	<0.001
3Bi	0.336	0.253	0.42	<0.001
3Bii	0.592	0.508	0.68	<0.001
3Biii	0.923	0.787	1.06	<0.001
3Biv	0.929	0.510	1.35	<0.001
3Ci	0.593	0.385	0.80	<0.001
3Cii	0.635	0.497	0.77	<0.001
3Ciii	0.983	0.821	1.15	<0.001
3Cv	0.496	0.396	0.60	<0.001
3Di	0.275	0.166	0.38	<0.001
3Dii	0.379	0.295	0.46	<0.001

Table 14: Exponentiated Linear Regression Parameters of Log Total Cost vs. DRG plus CPT Based Surgical Category

Parameter	Coefficient	2.5% CI	97.5% CI	p-value
(Intercept)	32476.76	28146.86	37472.74	<0.001
454	0.93	0.82	1.06	0.257
455	0.67	0.58	0.77	<0.001
456	0.99	0.83	1.19	0.955
457	0.78	0.68	0.90	0.001
458	0.52	0.45	0.60	<0.001
459	0.83	0.71	0.96	0.016
460	0.54	0.48	0.62	<0.001
471	0.69	0.58	0.81	<0.001
472	0.47	0.41	0.54	<0.001
473	0.40	0.35	0.46	<0.001
490	0.27	0.24	0.31	<0.001
491	0.20	0.18	0.24	<0.001
518	0.32	0.21	0.50	<0.001
519	0.29	0.25	0.34	<0.001
520	0.22	0.19	0.25	<0.001
1Aii	1.33	1.26	1.42	<0.001
1Bi	1.19	1.06	1.33	0.002
1Bii	1.72	1.50	1.96	<0.001
1Cii	4.93	2.76	8.80	<0.001
1Civ	1.81	1.65	1.99	<0.001
1Di	1.86	1.72	2.02	<0.001
1Dii	2.18	1.99	2.38	<0.001
2Ai	1.48	0.97	2.25	0.068
2Aii	2.08	1.54	2.81	<0.001
2Bi	1.07	0.92	1.26	0.381
2Bii	1.62	1.44	1.81	<0.001
2Biii	2.31	2.07	2.58	<0.001
2Biv	2.59	2.17	3.08	<0.001
2Ci	2.04	1.34	3.11	0.001
2Cii	3.22	1.80	5.76	<0.001
2Civ	2.80	1.55	5.08	0.001
2Di	1.71	1.59	1.84	<0.001
2Dii	1.86	1.54	2.26	<0.001

3Ai	1.43	1.30	1.56	<0.001
3Bi	1.40	1.29	1.52	<0.001
3Bii	1.81	1.66	1.97	<0.001
3Biii	2.52	2.20	2.89	<0.001
3Biv	2.53	1.66	3.85	<0.001
3Ci	1.81	1.47	2.23	<0.001
3Cii	1.89	1.64	2.17	<0.001
3Ciii	2.67	2.27	3.14	<0.001
3Cv	1.64	1.49	1.82	<0.001
3Di	1.32	1.18	1.47	<0.001
3Dii	1.46	1.34	1.59	<0.001

Table 15: Comparison of DRG and CPT Based Surgical Category Models

	Training Adjusted R^2	Validation Adjusted R^2	AIC	BIC	Correlation of Predicted vs. Actual Total Cost
MS-DRG	0.655	0.619	2438.020	2542.807	0.784
CSC	0.571	0.535	3213.908	3404.990	0.728
MS-DRG + CSC	0.744	0.708	1418.947	1702.488	0.836