Published in final edited form as:
Spine J. 2010 October ; 10(10): 881–889. doi:10.1016/j.spinee.2010.07.391.

Comparative In-Hospital Morbidity and Mortality after Revision versus Primary Thoracic and Lumbar Spine Fusion

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Abstract

Background Context—Despite increasing utilization of surgical spine fusions, a paucity of literature addressing perioperative complications after revision (RPSF) versus primary posterior spine fusions (PPSF) of the thoracic and lumbar spine exists.

Purpose—To examine demographics of patients undergoing PPSF and RPSF of the thoracic and lumbar spine, assess the incidence of perioperative morbidity and mortality, and determine independent risk factors for in-hospital death.

Study Design/Setting—Analysis of nationally representative data collected for the National Inpatient Sample (NIS).

Patient Sample—All discharges included in the NIS with a procedure code for posterior thoracic and lumbar spine fusion from 1998 to 2006.

Outcome Measures—In-hospital mortality and morbidity.

Methods—Data collected for each year between 1998 and 2006 for the National Inpatient Sample were analyzed. Discharges with a procedure code for thoracic and lumbar spine fusion were included in the sample. The prevalence of patient as well as health care system related demographics were evaluated by procedure type (primary vs. revision). Frequencies of procedure-related complications and in-hospital mortality were analyzed. Independent predictors for in-hospital mortality were determined.

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Classification: clinical study (level III)

Results—We identified 222,549 PPSF and 12,474 RPSF discharges between 1998 and 2006. Patients undergoing PPSF were significantly younger (51.23 (CI= [51.16, 51.31]) years) and had lower average comorbidity indices (0.40 (CI= [0.39, 0.41]) than those undergoing RPSF (52.69 (CI= [52.43, 52.97]) years and 0.44 (CI=[0.43, 0.45]), P<0.0001). The incidence of procedure related complications was 16.02% among RPSF compared to 13.44% in PPSF patients (P<0.0001). In-hospital mortality rates after PPSF were approximately twice those of RPSF (0.28% vs. 0.15%, P=0.006). Adjusted risk factors for increased in-hospital mortality included PPSF compared to RPSF, male gender, and increasing age. A number of comorbidities, complications, and specific surgical indications increased the risk for perioperative death.

Conclusion—Despite being performed in generally younger and healthier patients, and having lower perioperative morbidity, PPSF procedures are associated with increased mortality compared with RPSF procedures. The findings of this study can be used for risk stratification, accurate patient consultation, and hypothesis formation for future research.

Keywords

Spinal Fusion; Revision; Lumbar spine; Complications; Mortality; Morbidity

Introduction

Lumbar surgery rates have dramatically increased over the past 2 decades in the US. Fusion procedures in particular increased by approximately 220% since 1990.[6,20] Furthermore, the cumulative incidence of reoperation following lumbar fusion surgery is substantial, with rates up to 20.1% being reported at 10 years.[10] However, despite the increasing utilization of these procedures, a paucity of nationally representative outcome data comparing primary and revision spine fusion surgery exists. Knowledge of the incidence of peri-operative complications and adverse events following primary and revision lumbar fusion is critical for physicians in order to anticipate clinical needs and adequately inform patients of the risks involved.

The purpose of the this study was to utilize data collected for the National Inpatient Sample (NIS) to 1) identify patient and health care system related demographics associated with the utilization of both primary (PPSF) and revision (RPSF) posterior spinal fusion procedures; 2) to determine the incidence of perioperative complications in a comparative fashion and 3) to identify risk factors associated with morbidity and mortality in these procedures. These data may help physicians identify patients at risk and direct future research to improve perioperative outcomes.

Materials and Methods

Study sample and analysis

As part of the Healthcare Cost and Utilization Project (HCUP), the NIS is sponsored by the Agency for Healthcare Research and Quality (AHRQ). The NIS is the largest all-payer inpatient care database in the United States; containing data from approximately 8 million hospital stays from about 1,000 hospitals sampled to approximate a 20% stratified sample of U.S. community hospitals. To be able to produce national estimates, both hospital and discharge weights are provided, along with information necessary to calculate the variance of estimates. The data provided includes ample information on patient demographics, payment source, length of stay, hospital characteristics, and up to 15 ICD-9 diagnostic and procedure codes. More detailed information on the NIS design can be found at www.hcup-us.ahrq.gov/nisoverview.jsp.

All variables in this study were created based on the data available from the NIS between the years 1998 and 2006. Primary and revision thoracic and lumbar spine fusion procedures (ICD-9 codes of 8105/8108 and 8135/8138, respectively) were identified and selected. Patient and health care system related demographics included age, gender, race, and primary source of payment. Hospital characteristics were represented by hospital size, hospital location, and hospital teaching status. Definitions for hospital classification (hospital bedsize, hospital location, and hospital teaching status) can be found in Appendix A. Procedure-related complications were obtained using a list of ICD-9-CM diagnosis codes specifying complications of surgical and medical care (ICD-9-CM 996.X to 999.X) (Appendix B). The indication for surgery was determined by the presence of ICD-9-CM diagnosis codes specifying degenerative disc disease, spinal stenosis, scoliosis, spondylolisthesis, traumatic indications, and oncologic indications (Appendix B). In addition, selected adverse diagnoses including pulmonary embolism, venous thrombosis, and respiratory insufficiency after trauma or surgery/ Adult Respiratory Distress Syndrome (ARDS), and acute post-hemorrhagic anemia were considered in this study (Appendix B). A set of comorbidity measures was assigned using the Clinical Classification Software that was provided by the AHRQ (http://www.hcup us.ahrq.gov/toolssoftware/ccs/ccs.jsp).[3] In order to assess the overall comorbid burden, comorbidity indices were calculated as described by Charlson et al.[2] and adjusted for use with administrative data by Deyo et al.[4] As data that is used in this study is sufficiently de-identified, this study was exempt from review by the institutional review board.

Statistical Analysis

In order to identify risk factors for in-hospital mortality after spine surgery, both univariate and multivariate statistical analysis were performed. Univariate analysis consists of assessing differences in demographics of discharges, underlying diagnoses, and procedure related complications after spine surgery between procedure types (primary spine fusion vs. revision spine fusion) and between mortality status (alive vs. dead). Chi-square tests and t-tests were used to evaluate the significance in the univariate analysis for discrete variables and continuous variables, respectively. Four multiple logistic regression models were constructed to identify independent risk factors for in-hospital morbidity and mortality (Table 1). Models 1-3 were constructed to evaluate the comorbidity index, individual comorbidities, as well as procedure related complications as potential risk factors for in-hospital mortality, respectively. Model 4 was to determine the impact of individual comorbidities on the occurrence of any procedure related complications. All four models were adjusted by the same set of covariates including gender, race (e.g. white, black, Hispanic, other), age in years (e.g. 0-44, 45-64, 65-75, >=75), primary payer (e.g., Medicare, Medicaid, Private or others), hospital location (e.g. urban, rural), hospital size (e.g. small, medium, large) and hospital teaching status (e.g. teaching, non-teaching), procedure type (e.g. primary spine surgery, revision spine surgery), and surgical indications (e.g. degenerative disc disease, spinal stenosis, scoliosis, spondylolisthesis, traumatic indications, oncologic indications, multiple indications, other). The first model was created to evaluate the effect of demographic variables and the overall effect of comorbidity using the Deyo comorbidity index as a predictor. In the second model, individual comorbidities were substituted for comorbidity index in order to determine the impact of specific comorbidities on mortality. The third model was chosen to identify risk factors among procedure related complications for mortality while controlling for overall comorbidity burden (Deyo comorbidity index). All statistical analyses were performed using SAS procedures developed for complex survey (e.g. PROC SURVEYMEANS, PROC SURVEYFREQ, and PROC SURVEYLOGISTIC) to account for weights, clusters and strata used in the NIS (SAS Version 9.1.3, SAS Institute, Cary, NC). Continuous variables were presented as means and 95% confidence intervals (CIs), and categorical variables were described as percentages. For each individual predictor in the logistic regression models, the odds ratio (OR), 95% CI of OR,

and p-value were computed. Due to the large sample size, a p-value of 0.001 was used to define significant differences.

Results

Demographics

A summary of patient and hospital characteristics by procedure type is shown in Table 2. A total number of 222,549 PPSF and 12,474 RPSF discharges between 1998 and 2006 were identified, representing a weighted national estimate of 1,082,931 and 59,926 hospitalizations for each procedure, respectively. The majority of posterior spine fusions (PSF) patients were female (55.34% of PPSF and 57.39% of RPSF) and white (88.11% of PPSF and 89.88% of RPSF). In addition, most PSFs were performed in hospitals that were large (66% of PPSF and 68.78% of RPSF), in an urban environment (95.28% of PPSF and 97.66% of RPSF), and teaching institutions (57.99% of PPSF and 60.17% of RPSF). Patients undergoing PPSF were significantly younger on average than those undergoing RPSF (51.23 (CI=[51.16, 51.31]) years for PPSF and 52.69 (CI=[52.43, 52.97]) years for RPSF, P<0.0001). A larger proportion of PPSFs were performed among patients who were below the age of 45 when compared to RPSFs (34.33% versus 29.66%). A higher proportion of admissions undergoing PPSF were privately insured compared to RPSF, most likely because the younger patients did not qualify for government services. The majority of discharges in each procedure were routine discharges and comparable between the two groups (69.83% of PPSF and 69.28% of RPSF, P<0.0001). RPSF was associated with higher overall comorbidity burden (Deyo comorbidity index 0.44 (CI=[0.43, 0.45]) for RPSF and 0.40 (CI=[0.39, 0.41]) for PPSF, P<0.0001).

Outcomes after PPSF and RPSF

Complications considered procedure related were more frequent among RPSF compared to PPSF patients (16.02% vs. 13.44%, P<0.0001) (Table 3). The incidences of pulmonary embolism (0.28% vs. 0.32%, P=0.3796), venous thrombosis (0.58% vs. 0.63%, P=0.5438), adult respiratory distress syndrome (1.26% vs. 1.37%, P=0.2519), and acute post-hemorrhagic anemia (12.4% vs. 11.94%, P=0.1331) were similar between PPSF and RPSF. In-hospital mortality rate was higher among PPSF than RPSF (0.28% vs. 0.15%, P=0.006). The average age of fatalities after PPSF and RPSF was similar (64.08 (CI=[62.72, 65.44]) vs. 66.13 (CI=[61.10, 71.15]), P=0.2163). Mortalities after RPSF occurred sooner after admission to the hospital compared to PPSF (12.64 days (CI= [6.31, 18.98]) vs. 18.65 days (CI= [16.95, 20.35]), but this difference was not significant (P=0.0732).

Traumatic indications and oncologic indications were significantly more frequent, and degenerative disc disease less frequent among mortalities when compared to survivors in PPSF (P<0.0001) (Table 4). Oncologic indications were significantly more frequent, and spinal stenosis and spondylolisthesis were less frequent among mortalities when compared to survivors in RPSF (P<0.0001).

Risk Factors for Peri-operative Morbidity and Mortality after PSF

Multiple logistic regression Model 1 revealed a number of independent risk factors for mortality after PSF. Patient demographics that were associated with increased perioperative mortality included male gender (OR 1.61, CI=[1.36, 1.9], P<0.0001), and age (age above 75: OR 23.73, CI=[15.62, 36.03], P<0.0001; age between 65 and 75: OR 13.18, CI=[8.8, 19.74], P<0.0001; age between 45 and 65: OR 4.76, CI=[3.53, 6.41], P<0.0001 when compared to those aged below 45). PPSF procedures were associated with higher risk for mortality compared to RPSF surgeries (OR 2.52, CI=[1.56, 4.08], P=0.0002). Patients insured by Medicaid were associated with increased mortality compared to private including HMO (OR 2.04, CI=[1.47, 2.83], P<0.0001). Surgeries undertaken in teaching hospitals were associated

with higher odds of perioperative mortality compared to non-teaching hospitals (OR 1.43 CI=[1.2, 1.71], P<0.0001). No other patient demographics and health care system related characteristics were identified as significant risk factors for mortality.

The estimate of the impact of overall comorbidity burden on mortality was obtained by logistic regression Model 1 when controlling for surgical indications. We found that perioperative mortality increased was unaffected by the comorbidity index (OR 1.04, CI=[0.95, 1.14], P=0.4031). However, a number of comorbidities identified by logistic regression Model 2 (Table 5) were associated with higher risk of mortality, among which pulmonary circulatory disease carried the highest odds of perioperative mortality (OR 8.61, CI=[5.93, 12.49], P<0.0001).

When controlling for overall comorbidity burden, patient demographics, health care system related characteristics, and surgical indications, a number of procedure related complications (revealed by logistic regression Model 3) were associated with an increased risk of perioperative mortality. Among those with the highest increase were complications affecting the central nervous system (OR 4.2, CI=[2.81, 6.29], P<0.0001), cardiac system (OR 7.36, CI=[5.41, 9.99], P<0.0001), shock (OR 8.81, CI=[4.33, 17.91], P<0.0001), and infection (OR 2.63, CI=[1.66, 4.15], P<0.0001) (Table 6). In Models 1-3, scoliosis, traumatic, oncologic, and other indications were consistently identified as significant risk factors for perioperative mortality when compared to degenerative disc disease. Traumatic and oncologic indications were associated with the highest odds ratios in these three models.

Risk factors for perioperative procedure related complications were identified by logistic regression Model 4 (Table 7), and included: male gender (OR 1.16, CI=[1.13, 1.19], P<0.0001), older age (age above 75 OR 1.72, CI=[1.62, 1.83], P<0.0001; age in 65-75 OR 1.58, CI=[1.5, 1.67], P<0.0001; age in 45-64 OR 1.29, CI=[1.24, 1.33], P<0.0001 when compared to age below 44), race (Black OR=1.17, CI=[1.1, 1.23], P<0.0001 and OR=1.2, CI=[1.09, 1.31], P<0.0001 when compared to White and Other, respectively), type of insurance (Medicaid OR 1.13, CI=[1.08, 1.20], P<0.0001 when compared to private including HMO; Medicaid OR 1.15, CI=[1.09, 1.23], P<0.0001 when compared to other), hospital bed size (large OR=1.09, CI=[1.05, 1.14], P<0.0001; medium OR 1.08, CI=[1.04, 1.13], P<0.0001 when compared to small), and teaching hospital (OR=1.11, CI=[1.08, 1.14], P<0.0001). RPSF procedures were associated with higher odds of procedure related complications compared to PPSF (OR 1.2, CI=[1.14, 1.26], P<0.0001). A set of comorbidities were determined as risk factors for procedure related complications, among them: coagulopathy (OR 1.99, CI=[1.83, 2.16], P<0.0001), pulmonary circulatory disease (OR 2.18, CI=[1.89, 2.52], P<0.0001), and electrolyte/fluid abnormalities (OR 2.16, CI=[2.07, 2.25], P<0.0001). Among surgical indications, only scoliosis and multiple indications were associated with significant increased risk for perioperative procedure related complications when compared to degenerative disc disease (scoliosis: OR 1.61, CI=[1.53, 1.70], P<0.0001; multiple indications: OR 1.07, CI=[1.04, 1.11], P<0.0001).

Discussion

This study used data collected for the NIS between the years of 1998 and 2006 to compare short term morbidity and mortality after primary and revision spinal fusions and identify risk factors for such events among these procedures. RPSF procedures were associated with an increased incidence of perioperative complications when compared to PPSF. In contrast, PPSF were associated with increased adjusted risk of in-hospital mortality when compared to RPSF procedures. Risk factors identified as having increased in-hospital mortality included male gender, advanced age, teaching hospital, and Medicaid insurance. In the setting of an increased utilization of posterior spinal fusion procedures, the findings of this study are useful to the

treating surgeon and perioperative physicians in order to better evaluate the risk of perioperative mortality and morbidity among patients and educate patients of these risks prior to undertaking surgical procedures.

The number of primary and revision procedures that were identified in this time period clearly reflects a national increase in the utilization of PSFs for the treatment of spine-related disorders. This trend has also been noted in several prior studies.[6,20] Weinstein et al.[24] performed a repeated cross-sectional analysis using national Medicare data from 1992-2003 and found that rates and subsequently expenditures increased significantly in that time period, with spending for lumbar fusion increasing more than 500%.[24] It is notable that most PSFs were performed in individuals that were white and female, and at hospitals that were large, in an urban environment, and teaching centers. Whether or not this is related to a disparity in health-care accessibility for conditions requiring PSF or a different threshold for surgeons recommending such procedures can only be answered by future studies better designed to address these questions. The results of this study also revealed that patient populations undergoing PPSF and RPSF tend to have distinct demographic characteristics, with patients undergoing PPSF more likely to be younger and privately insured. These findings are somewhat intuitive given the age limitations of Medicare coverage in the U.S.

Further, we found that revision fusions were associated with higher procedure-related complication rates. Analysis using multiple logistic regression revealed that RPSF were independently associated with higher odds of experiencing a procedure related complication relative to PPSF. Although speculative, it is likely related to the increased technical difficulty associated with these procedures and longer operative times. The findings of this study echo those of previous non-comparison series performed at single centers, which have collectively found that revision spinal fusions in adults carry a significant risk of complications (up to 25%).[11,25] Similar findings have also been noted for revision anterior lumbar fusions. In a retrospective review of 129 consecutive patients undergoing anterior lumbar revision fusions, complication rates were found to be 3 to 5 times higher than reported for primary lumbar exposures.17 Interestingly, in their series complication rates were significantly higher for revision anterior lumbar fusions at the same segment, which were typically in the lower lumbar spine, compared with cases involving extensions, which were typically in the upper lumbar spine.17 Unfortunately, our data did not evaluate whether complication rates were segment specific, as such information is not available in our data set.

PPSF were associated with a higher mortality in our study, despite being performed on younger individuals with lower comorbidity burden. To our knowledge this finding has yet to be reported in the literature on such a scale. Although speculative, we attributed this finding to several factors. Primary fusions are more likely to be performed in an emergent setting for indications such as traumatic instability and cord/cauda compression; thus not allowing for extensive pre-operative evaluation and optimization. Secondly, common indications for revision spine surgery include minor procedures, such as removal of symptomatic hardware as well as augmentation of a fusion mass, which are less extensive than the initial procedure. Lastly, in revision cases there is by definition a pre-selection of patients that are more likely to survive spine fusion surgery as they have survived the initial procedure.

Several patient demographics were also found to be independent risk factors of experiencing a fatal event following PSF. This is not the first study to identify male gender as a risk factor for a fatal event after spine fusion, yet the reason behind this remains unclear.14[,18] Similarly, we identified an increased incidence of mortality and risk for mortality in patients with advanced age (>65 years). We also noted this trend to be increasingly true in patients older than 75, which represented a disproportionate number of deaths in this series. In addition, this trend cannot be explained by increasingly comorbidity burden, as it persisted when controlling

for this. In contrast, earlier literature has not been consistent with regards to this finding.[1,8,16]

Our analysis showed that surgeries undertaken in teaching hospitals were associated with higher odds of perioperative mortality. The results of our analysis may be due to the fact that the surgical procedures performed at teaching hospitals represent more complex cases and higher risk patient populations being treated, although we were unable to prove this based on the available data.

In this study, both increasing comorbidity burden and several other systemic diseases were found to be associated with increased risk of perioperative complications and overall mortality, which is consistent with prior studies.[8,14,18] Of these, pulmonary circulatory disease was associated with the highest risk of perioperative mortality. This finding is unique in the currently available literature as very few studies have identified this as a notable risk factor.[12,18] Our recent publication using NIS data to compare mortality based on surgical approaches was one of the first to document this.[12] We hypothesized that patients with pulmonary hypertension and decreased right ventricular reserve may be less likely to deal with the consequences of pulmonary embolization of bone and marrow material during instrumentation, resulting in increases in pulmonary vascular resistance.[12] This was based on earlier work documenting increased pulmonary vascular resistance[21], bronchoalveolar specimens demonstrating lipid laden macrophages[22], and echocardiographic studies documenting embolization after posterior instrumentation. [19]

Traumatic and oncologic indications for surgery carried an increased risk for in-hospital mortality in our study. This is consistent with reports in the literature and higher mortality may be explained by increased surgical complexity and the fact that traumatic admissions require treatment for associated injuries that are potentially life-threatening[23]. With regards to oncologic procedures, it has been proposed that diminished physical reserve, a weakened immune system, and adjuvant therapy contribute to a higher rate of perioperative complications among this group[5].

There were a number of procedure related complications that were associated with an increased risk of perioperative mortality; including central nervous, cardiac, local wound and infection related complications as well as perioperative shock. It is important to note that these were determined after controlling for overall comorbidity burden, surgical indications, patient demographics, and health care system related characteristics. However, it has to be considered that these risk factors are shared by patient populations undergoing other types of surgery and are not unique to spine procedures. [13] In addition, although the association between local wound complications (infection hematoma, wound dehiscence) and increased morbidity and mortality has been made in the past[7], this study emphasizes the importance of implementing proven techniques to minimize such complications, such as the administration of antibiotics preoperatively and in the immediate postoperative period, the avoidance of shaving the incisional area immediately prior to surgery, and adequate preparation of the skin. 9.15

This study is limited by a number of factors inherent to secondary data analysis of large administrative databases. As such, clinical information and that detailing the surgical procedure (i.e. type of anesthesia, amount of blood loss, length of surgery etc.) available in the NIS is limited and our analysis must be interpreted in this context. Although gathering data on the number of levels operated on may theoretically be possible through the use of the ICD-9-CM coding system, this information was missing in about two thirds of patient entries, thus making the inclusion of this variable in our analysis not feasible. Because of the nature of the NIS, only in-patient data are available and thus complications and events after discharge are not captured. Thus, conclusions should be limited to the acute perioperative setting with the notion that

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mortality and complications are likely underestimated. Furthermore, readmissions and the reason that revisions were performed cannot be discerned with certainty from this database. An additional limiting factor is the bias associated with the retrospective nature of our study (i.e. inability to obtain data other than those collected, historic nature). Nevertheless, because of the availability of data from a large, nationally representative sample, this type of analysis may provide a more accurate estimate of demographic variables and complications surrounding primary and revision thoracic and lumbar spine fusion procedures than various prospective studies that are limited in sample size and lack the ability to capture low-incidence outcomes.

In conclusion, detailed analysis of data from a nationally representative database revealed that RPSF carried a greater incidence of in-hospital complications but a decreased adjusted risk of in-hospital mortality when compared to PPSF. Our data can be used to educate patients on the risks and consideration of alternative treatment modalities before undergoing spinal fusion. Further, this information is helpful for treating physicians to assess perioperative risk in such procedures and to guide future research in this area.

Appendix A: Hospital Classification in the HCUP-NIS

The following information was obtained from the HCUP-NIS website. Detailed description of data elements in the NIS can be found at http://www.hcup-us.ahrq.gov/db/nation/nis/nisdde.jsp .

1. Hospital bedsize

Bedsize categories are based on hospital beds, and are specific to the hospital's location and teaching status (rural, urban nonteaching, urban teaching). It is also defined differently by regions (northeast, midwest, southern, western).In general small hospitals ranged in bed numbers between 1-249, medium hospitals 250-449, and large hospitals 450 or more. Hospital location

2. Hospital location

The classification of urban or rural location in the HCUP-NIS is based on information obtained from the AHA Annual Survey of Hospitals. A Metropolitan Statistical Area (MSA) was considered urban, and a non-MSA was classified as rural.

3. Hospital teaching status

The hospital's teaching status was obtained from the AHA Annual Survey of Hospitals. Teaching and nonteaching hospitals differ in the missions and financial considerations. According to the HCUP-NIS, “a hospital is considered to be a teaching hospital if it has an AMA-approved residency program, is a member of the Council of Teaching Hospitals (COTH) or has a ratio of full-time equivalent interns and residents to beds of .25 or higher.”

Appendix B: List of International Classification of Diseases, 9th Revision, Clinical Modification, Diagnosis Codes Included to Identify Comorbidities, Adverse Diagnosis, and Complications among Discharges

Procedure-related complications	
Device related	996
Central nervous system	9970

Cardiac	9971
Peripheral vascular	9972
Respiratory	9973
Gastrointestinal	9974
Genitourinary	9975
Other organ specific	9976–9979
Postoperative shock	9980
Hematoma/seroma	9981
Accidental puncture/laceration	9982
Disruption operative wound	9983
Postoperative infection	9985
Other complications of procedure	9986–9989
Complications of medical care	999
Other adverse events	
Acute posthemorrhagic anemia	2851
Pulmonary embolism	4151
Pulmonary insufficiency after trauma and surgery/adult respiratory distress syndrome	5185
Venous thrombotic events	4511, 4512, 4518, 4519, 4532, 4538, 4539
Surgical indications	
Degenerative disc disease	721.0-9, 722.0-9
Spinal stenosis	724.0-09
Scoliosis	737.0-9
Spondylolisthesis	738.4
Traumatic indications	800.0 – 899.9
Oncologic indications	198.3, 198.4, 198.5

Multiple indications: all entries that have at least two of the above indications

Other indications: all entries that do not include any of the above ICD9 codes for surgical indications

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Table1

Multiple Logistic Regression Models

	Model 1	Model 2	Model 3	Model 4
Outcomes	Vital status (died/alive)	Vital status (died/alive)	Vital status(died/alive)	Any procedure related complication(yes/no)
Predictors	Comorbidity index	Individual comorbidities	Perioperative procedure related complications	Individual comorbidities
Covariates	Procedure types, surgical indications, patient demographic and health care system related variables	Procedure types, surgical indications, patient demographic and health care system related variables	Procedure types, comorbidity index, surgical indications, patient demographic and health care system related variables	Procedure types, surgical indications, patient demographic and health care system related variables

Table 2

Demographics of Primary- and Revision Posterior Thoracic and Lumbar Spine Fusion Discharges

Posterior Lumbar Spine Fusion Type	Primary	Revision	p-value
N (Sample Size)	222,549	12,474	
	% of total	% of total	
Age groups (years)			<0.0001
0-44	34.33	29.66	
45-64	39.78	46.30	
65-75	16.33	16.50	
>75	9.55	7.54	
Gender			<0.0001
Male	44.66	42.61	
Female	55.34	57.39	
Race			<0.0001
White	83.55	86.19	
Black	6.65	6.04	
Hispanic	6.14	5.03	
Other	3.66	2.73	
Insurance			<0.0001
Medicare	28.21	31.82	
Medicaid	5.80	4.77	
Private/ HMO	49.86	45.49	
Other	16.13	17.93	
Discharge Status			<0.0001
Routine	69.83	69.28	
Short Term Hospital	0.55	0.38	
Other Transfers	17.67	16.52	
Home Health Care	11.58	13.57	
Against Medical Advice	0.06	0.09	
Died in Hospital	0.28	0.15	
Alive, Destination Unknown	0.01	0.01	
Hospital Size			<0.0001
Small	11.37	11.65	
Medium	22.63	19.57	
Large	66.00	68.78	
Hospital Location			<0.0001
Rural	4.72	2.34	
Urban	95.28	97.66	
Teaching Status			<0.0001
Non-teaching	42.01	39.83	

Posterior Lumbar Spine Fusion Type	**Primary**	**Revision**	**p-value**
N (Sample Size)	**222,549**	**12,474**	
	% of total	**% of total**	
Teaching	57.99	60.17	

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Table 3

Procedure Related Complications among Primary- and Revision Posterior Thoracic and Lumbar Spine Fusion Discharges

	Primary Posterior Lumbar Spine Fusion	Revision Posterior Lumbar Spine Fusion	P-value
	% of total	% of total	
Organ Specific Complications			
CNS	0.98	1.49	<0.0001
Cardiac	1.00	0.90	0.024
Peripheral Vascular	0.11	0.10	0.490
Respiratory	1.73	1.42	<0.0001
Gastrointestinal	2.48	2.46	0.742
Genitourinary	1.09	0.76	<0.0001
Other Complications of Procedure			
Shock	0.09	0.07	0.183
Hematoma/Seroma	1.65	2.54	<0.0001
Puncture Vessel/Nerve	3.32	4.67	<0.0001
Wound Dehiscence	0.22	0.44	<0.0001
Infection	0.60	1.48	<0.0001
Other	2.17	2.29	0.058
Medical Complication	0.20	0.26	0.001

Table 4

Incidence of Underlying Diagnoses for Thoracic and Lumbar Spine Fusion by Procedure Type and Vital Status

Posterior Lumbar Spine Fusion Type	Primary		Revision	
	Died	Alive	Died	Alive
N (Sample Size)	(n=617)	(n=221,436)	(n=19)	(n=12,384)
	% of died	% of alive	% of died	% of alive
Degenerative Disc Disease	14.27	40.98	26.01	28.47
Spinal stenosis	8.75	8.83	5.79	9.65
Scoliosis	7.29	6.83	5.37	6.74
Spondylolisthesis	3.51	5.33	0	3.77
Traumatic Indications	21.87	4.07	0	0.82
Oncologic Indications	15.77	0.89	4.85	0.33
Multiple Indications	14.24	27.44	26.36	18.39
Other	14.31	5.63	31.62	31.84

Table 5

Risk Factors for Perioperative Mortality after Posterior Thoracic and Lumbar Spine Fusion –Comorbidities and Surgical Indications (Model 2)

	Odds Ratio	Lower -95%CI	Upper -95%CI	P-Value
Comorbidity				
Alcohol Abuse	0.828	0.446	1.54	0.552
Chronic Lung Disease	1.107	0.878	1.396	0.39
Congestive Heart Failure	***3.781***	***2.9***	***4.93***	***<0.0001***
Uncomplicated Diabetes Mellitus	1.609	1.184	2.186	0.002
Complicated Diabetes Mellitus	1.141	0.654	1.991	0.642
Liver Dysfunction	***3.026***	***1.718***	***5.331***	***<0.0001***
Coagulopathy	***5.041***	***3.88***	***6.548***	***<0.0001***
Neurologic Disorders	***2.523***	***1.832***	***3.474***	***<0.0001***
Obesity	0.646	0.38	1.096	0.105
Peripheral Vascular Disease	1.112	0.643	1.924	0.705
Renal Disease	***2.906***	***1.872***	***4.509***	***<0.0001***
Pulmonary Circulatory Disease	***8.608***	***5.933***	***12.489***	***<0.0001***
Cardiac Valvular Disorders	1.236	0.862	1.772	0.25
Electrolyte/Fluid Abnormalities	***2.334***	***1.894***	***2.876***	***<0.0001***
Metastatic Cancer	1.715	0.956	3.077	0.07
Weight Loss	***3.155***	***2.17***	***4.588***	***<0.0001***
Surgical Indication				
Spinal Stenosis*	1.226	0.872	1.724	0.241
Scoliosis*	***3.308***	***2.22***	***4.928***	***<0.0001***
Spondylolisthesis*	1.374	0.836	2.257	0.21
Traumatic Indications*	***9.55***	***7.073***	***12.894***	***<0.0001***
Oncologic Indicatiuons*	***9.672***	***5.565***	***16.81***	***<0.0001***
Other Indications*	***4.159***	***3.059***	***5.655***	***<0.0001***
Multiple Indications*	0.792	0.589	1.063	0.12

* **Degenerative disc disease was used as reference.**

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Table6

Risk Factors for Perioperative Mortality after Posterior Thoracic and Lumbar Spine Fusion-Procedure Related Complications and Surgical Indications (Model 3)

Complications	Odds Ratio	Lower-95%CI	Upper -95%CI	P-Value
Organ Specific Complications				
CNS	***4.202***	***2.805***	***6.294***	***<0.0001***
Cardiac	***7.356***	***5.414***	***9.993***	***<0.0001***
Peripheral Vascular	0.838	0.264	2.662	0.765
Respiratory	1.656	1.118	2.452	0.012
Gastrointestinal	1.23	0.785	1.928	0.366
Genitourinary	1.073	0.614	1.875	0.805
Other Complications of Procedure				
Shock	***8.811***	***4.334***	***17.912***	***<0.0001***
Hematoma/Seroma	1.462	0.938	2.279	0.093
Puncture Vessel/Nerve	1.229	0.827	1.826	0.308
Wound Dehiscence	1.883	0.9	3.939	0.093
Infection	***2.626***	***1.661***	***4.151***	***<0.0001***
Other	0.551	0.255	1.189	0.129
Medical Complication	0.754	0.176	3.236	0.704
Surgical Indication				
Spinal Stenosis*	1.254	0.894	1.759	0.191
Scoliosis*	***4.029***	***2.695***	***6.024***	***<0.0001***
Spondylolisthesis*	1.341	0.834	2.154	0.226
Traumatic Indications*	***10.221***	***7.494***	***13.941***	***<0.0001***
Oncologic Indicatiuons*	***15.98***	***11.345***	***22.51***	***<0.0001***
Other Indications*	***4.917***	***3.595***	***6.725***	***<0.0001***
Multiple Indications*	0.806	0.598	1.086	0.156

* **Degenerative disc disease was used as reference.**

Table7

Risk Factors for Procedure Related Complications after Posterior Thoracic and Lumbar Spine Fusion – Comorbidities and Surgical Indications (Model 4)

	Odds Ratio	Lower -95%CI	LUpper -95%CI	P-Value
Comorbidity				
Alcohol Abuse	0.984	0.875	1.106	0.783
Chronic Lung Disease	1.047	1.009	1.087	0.015
Congestive Heart Failure	***1.721***	***1.593***	***1.859***	***<0.0001***
Uncomplicated Diabetes Mellitus	1.06	1.017	1.105	0.006
Complicated Diabetes Mellitus	1.105	0.987	1.239	0.084
Liver Dysfunction	1.22	1.062	1.402	0.005
Coagulopathy	***1.987***	***1.83***	***2.157***	***<0.0001***
Neurologic Disorders	***1.264***	***1.181***	***1.354***	***<0.0001***
Obesity	***1.133***	***1.078***	***1.192***	***<0.0001***
Peripheral Vascular Disease	0.992	0.896	1.098	0.875
Renal Disease	1.01	0.872	1.17	0.892
Pulmonary Circulatory Disease	***2.184***	***1.893***	***2.519***	***<0.0001***
Cardiac Valvular Disorders	1.083	1.01	1.162	0.026
Electrolyte/Fluid Abnormalities	***2.158***	***2.072***	***2.248***	***<0.0001***
Metastatic Cancer	1.085	0.9	1.308	0.392
Weight Loss	***1.785***	***1.541***	***2.067***	***<0.0001***
Surgical Indication				
Spinal Stenosis*	1.011	0.966	1.058	0.64
Scoliosis*	***1.612***	***1.533***	***1.696***	***<0.0001***
Spondylolisthesis*	0.971	0.916	1.029	0.321
Traumatic Indications*	0.942	0.878	1.011	0.096
Oncologic Indicatiuons*	1.213	1.027	1.433	0.023
Other Indications*	1.084	1.03	1.141	0.002
Multiple Indications*	***1.071***	***1.037***	***1.105***	***<0.0001***

* **Degenerative disc disease was used as reference.**