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The Risk of Risk Adjustment Measures for Perioperative Spine Infection after Spinal Surgery

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Abstract

Study Design—Cross sectional data analysis of the Nationwide Inpatient Sample (NIS).

Objective—Develop a risk adjustment index specific for perioperative spine infection and compare this specific index to the Deyo Comorbidity Index (Deyo). Assess specific mortality and morbidity adjustments between teaching and non-teaching facilities.

Summary of Background Data—Risk adjustment measures have been developed specifically for mortality and may not be sensitive enough to adjust for morbidity across all diagnosis.

Methods—This condition specific index was developed using the NIS in a two step process to determine confounders and weighting. Crude and adjusted point estimates for the Deyo and condition specific index were compared for routine discharge, death, length of stay and total hospital charges then stratified by teaching hospital status

Results—A total of 23,846 perioperative spinal infection events occurred in the NIS database between 1988 and 2007 out of 1,212,241 procedures. Twenty-three diagnoses made up this condition specific index. Significant differences between the Deyo and the condition specific index were seen among total charges and length of stay at non-teaching hospitals ($p < 0.001$) and death, length of stay and total charges ($p < 0.001$) for teaching hospitals.

Conclusion—This study demonstrates several key points. One, condition specific measures may be useful when morbidity is of question. Two, a condition specific perioperative spine infection adjustment index appears to be more sensitive at adjusting for comorbidities. Finally, there are

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inherent differences in hospital disposition characteristics for perioperative spine infection across teaching and non-teaching hospitals even after adjustment.

Background

Measures of risk adjusted outcomes are commonly used during assessment of quality of surgical care^{1, 2}. Tangible characteristics are those provided by published information on quality of care or healthcare report cards³ and there is increasing evidence that consumers are interested in examining objective information⁴. Measures such as risk adjusted mortality rate (RAMI)^{5, 6}, hospital volume^{7–9}, and frequency measures of adverse impact or complications such as post-operative morbidity^{1, 8} have been used to describe hospital and surgeon performance and are readily available on consumer and government sponsored Internet sites. These sites provide comparative data on hospital and individual physician performance as a measure to supply patients and third party payers for informed decision making¹. Nonetheless, some controversy exists to whether risk adjustment is appropriate especially during occasions of small sample sizes and extremely high risk populations⁵.

RAMI has been criticized as a measure of quality for several reasons. Firstly, many surgical procedures are not performed frequently enough to obtain a viable measure of comparative mortality⁵. Secondly, measures often lack uniformity and data collecting mechanisms are disparate across institutions¹. Thirdly, historically, teaching hospitals see patients with more chronic conditions; conditions so advanced that the adjustment methods don't truly capture all the elements of variability⁶. Lastly, patients likely expect more from a surgical outcome outside of whether they survive (mortality). Better measures may include risk adjusted outcomes or other quality aspects that reflect morbidity upon recovery. In addition, adjustment of comorbidities has correlated poorly with other outcome measures^{10, 11} suggesting that different pathologies may require independent adjustments or adjustment beyond current allocated methods for appropriate comparisons.

The purpose of this study was to explore the impact of risk adjustment methods on mortality and morbidity between teaching and non-teaching facilities, specifically involving cases related to perioperative spine infection after spinal surgery. A comorbidity risk adjustment measure specific to perioperative spine infection may serve well to comparatively assess hospitals and physicians to better inform third party payers and consumers. This study investigated the differences in mortality and hospital disposition measures with no adjustment, adjustment using the Deyo Comorbidity Index¹² (a commonly used comorbidity-based adjustment index), and an adjustment using a novel tool specifically created for perioperative spine infection (condition specific index). Hospital disposition and morbidity measures may be a more accurate reflection of institutional variation among surgical recipients¹. We hypothesized that the condition specific index would lead to more specific mortality and morbidity adjustments and that the inherent differences between teaching and non-teaching facilities will lead to no significant variations after use of risk adjustment measures.

Methods

This study endeavored to develop a comorbidity index specific for perioperative spine infection and compare the results of this condition specific comorbidity index with a well established comorbidity index using a national representative sample. Data was collected using the Nationwide Inpatient Sample (NIS). The NIS database is part of the Healthcare Cost and Utilization Project (HCUP), sponsored by the *Agency for Healthcare Research and Quality* (AHRQ). The database records patient demographic information, patient medical diagnoses by Diagnostic Related Group (DRG), procedure information by the *International*

Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure code's primary and secondary diagnoses and procedural diagnoses, as well as hospital disposition variables such as length of stay, financial information, and admission and discharge information. This study targeted any spine surgical procedure associated with a decompression, disc repair, fusion, laminectomy, or disc repair of a past spine surgery (ICD-9 procedure codes: 03.0 03.09 03.02 03.6 80.50 80.51 80.52 80.59 81.00 81.0 81.04 81.05 81.09 79.50 78.59 78.60 78.69 78.90 78.99). Consequently, a litany of associative spine-related diagnoses were included if they included any of the operative procedures listed above. Information was captured regarding whether the procedure was performed at a teaching or non-teaching facility. The development of the condition specific comorbidity index consisted of two steps which are outlined below.

Step 1: Identifying potential factors associated with perioperative spinal infection

Potential confounders for this index were based upon clinical knowledge of one of the authors (BG) along with a review of the literature regarding known causal perioperative spine infection comorbidities. Using these potential confounders, ICD-9 codes were selected from the NIS database that would most closely match. A predictive multivariate model with the outcome of perioperative spine infection was used to evaluate comorbidities using a backward stepwise deletion to retain in the model. Covariates were retained if found to be significantly ($p < 0.10$) associated with the outcome of perioperative spine infection. This p -value was chosen to include comorbidities that may have a low prevalence's but may be important in the risk adjustment model. Table 1 describes the confounders, sample size and proportion of subjects with comorbidities found to be significantly associated with perioperative spine infection in the NIS.

Step 2: Development of a specific index for perioperative spinal infection

Scoring—This condition specific index was developed based upon weighted odds ratios from the model output similar to the development of the Deyo¹² and Charlson Comorbidity Indices¹³. "Weights" were assigned based upon the strength of the association of each confounder with perioperative spine infection. The odds ratio demonstrates the strength of the association between the covariate and perioperative spine infection and therefore those with greater odds ratios would receive greater weight in the model. Odds ratios with a value of less than 1.2 were discarded and those with a value of 1.2–2.5 were given a score of 1, odds ratios between 2.5 –3.5 were given a score of 2, odds ratios between 3.5 – 4.5 were given a score of 3 and so forth. This ranking is similar to that used in the development of the Deyo and Charlson Comorbidity Index. Overall, five comorbidities received a score of 1, twelve comorbidities received a score of 2, three comorbidities received a score of 3, one comorbidity received a score of 4 (Hemi or Paraplegia), one received a score of 5 (Thrombophlebitis) and one a score of 6 (Malnutrition).

Analysis—All analyses were performed using STATA 10 (StataCorp. 2009. Statistical Software: Release 10. College Station, TX: Stata Corporation). Independent covariates significantly associated with perioperative spine infection were modeled with unconditional binary logistic regression for categorical outcomes and linear regression for continuous outcomes. Perioperative surgical spine infection was defined as all subjects in the NIS who met the inclusion criteria with a diagnosis of surgical site infection (998.5 998.51 998.59), reaction to internal nervous system or orthopedic device (996.63 996.67) and non-healing surgical wound or disruption of operative wound (998.3 998.31 998.32). These codes were used based upon clinical knowledge of the authors and some of which have been used in previous literature to assess post surgical spine infection¹⁴. Perioperative surgical spine infection was treated as a binary exposure variable coded as no infection=0 and infection=1. Crude and adjusted odds ratios were used to compare the association with perioperative

spine infection and outcomes of routine discharge, length of hospital stay (in days), death, total hospital charges (in dollars) and routine discharge from hospital. Within the NIS, routine discharge is categorized into 8 possible groups, one of which is discharge to home. For this study, routine discharge was classified as a binary variable as discharge to one's home setting or otherwise. Results were then stratified based upon teaching versus non-teaching hospitals in the NIS.

To objectively measure the proportion of adjustment provided by the two comorbidity indexes a change in estimate formula from the unrounded beta coefficients was used. This change in estimate formula can be used to quantify the amount of adjustment between the crude and adjusted estimates¹⁵. This proportion was calculated by hand as the absolute value of the adjusted beta coefficient minus the crude beta coefficient. To quantify the difference in point estimates between the Deyo Comorbidity Index and the condition specific comorbidity index a test for homogeneity between odds ratios was used. Means from linear regression estimates were subtracted to quantify the difference between crude and adjusted estimates. These mean differences were then tested for significant differences with an independent t-test. All analysis of differences was done with an a priori alpha level of $p < 0.05$.

Results

Forty diagnoses were identified in both the literature review and based upon clinical knowledge of one of the authors (BG). There were twenty-three diagnoses that were found to be significantly associated ($p < 0.10$) with perioperative spinal infection (Table 1). A list of these confounders and their ICD-9 codes can be found in Appendix A. Diagnoses that were not significantly associated with the outcome in this analysis were; myocardial infarction, chronic pulmonary disease, diabetes, AIDS, cauda equina, body habitus, previous history of infectious disorder, previous history of endocrine metabolic and immunity disorder, hypertension, arrhythmia, urinary incontinence, osteoporosis, varicose veins, prior thoracotomy, adrenal insufficiency, psoriasis and fibromyalgia. The largest association with perioperative spinal infection was with the diagnosis of Thrombophlebitis or Malnutrition. The odds of perioperative spinal infection among those diagnosed with Malnutrition were 7.26 (95% CI 5.23, 10.07) times the odds of perioperative spinal infection among those without the diagnosis of Malnutrition while controlling for all other significant comorbidities. A similar association was seen with Thrombophlebitis. The odds of perioperative spinal infection among those diagnosed with Thrombophlebitis were 5.58 (95% CI 4.58, 6.81) times the odds of those without the diagnosis of Thrombophlebitis while controlling for all other significant comorbidities.

A description of the study population is outlined in Table 2. A total of 23,846 perioperative spinal infection events occurred in the NIS database between 1988 and 2007 out of 1,212,241 procedural events. The period prevalence of in-patient perioperative spine infection events from 1988 to 2007 was 1.97% (95% CI 1.94, 1.99). Of those with perioperative spine infection, the mean age was 51.2 years, Females represented 50.4% of these infections, 52.4% made \$35,000 or more per year, 30% were insured by Medicare and 43% had private insurance.

Descriptive statistics were also generated based upon hospital characteristics. The NIS uses a classification of hospitals based upon bed size as small, medium and large. Data from the AHA Annual Survey of Hospitals regarding number of short-term acute beds within the hospital are used to signify bed size classification. The majority (65.9%) of perioperative spinal infections occurred in large classified hospitals. In the NIS database hospitals are also classified based upon location region in the US. There did not appear to be any observable

difference in the occurrence of spinal perioperative infection based upon hospital region. Furthermore, hospitals are classified as government owned, private non-profit and private investor owned. A majority (75%) of perioperative spinal infections occurred in private nonprofit based hospitals.

Descriptive statistics were generated based upon characteristics related to both the individual and the hospital disposition including death, length of stay and total charges incurred during hospital stay. There were 325 (1.4%) deaths among those with perioperative spinal infection, about half (57.8%) of the patients were routinely discharged to home, the mean length of hospital stay among those with perioperative spinal infection was 11.5 days (95% CI 11.3, 11.7) and twice the length of stay of those without perioperative spine infection (3.8 days). The mean total charges among those with perioperative spinal infection were \$67,245.87 (95% CI \$52,971.29, \$55,219.06) and nearly twice than those without perioperative spine infection which totaled \$34,914.

Comparison of the Deyo and the condition specific comorbidity indexes

Table 3 describes the crude and adjusted estimates of our sample for the Deyo Comorbidity Index and the condition specific index. Routine discharge to home demonstrated a crude odds ratio of 0.22 (95% CI 0.22, 0.23). Those with perioperative spinal infection were 5.83 (95% CI 5.19, 6.54) times the odds of dying as those without perioperative spinal infection. When adjusting with the Deyo Comorbidity Index, mortality and hospital disposition variables had a moderate change in the adjusted estimate when compared to the overall crude estimate. The condition specific index made significant adjustments when compared to the Deyo in the crude estimate for length of stay, death and total charges when compared to the Deyo. The condition specific index significantly adjusted for 50% of the confounding in the crude estimate for death in addition significantly adjusted for approximately an additional 1/3 of a day in length of stay and an additional \$3,051 dollars in total charges when compared to the Deyo.

Tables 4 and 5 compare the results of the condition specific index with the Deyo Comorbidity Index across teaching and non-teaching hospitals. The odds ratio associated with routine discharge did not change significantly when stratified by teaching hospital status. The mean length of stay was 10.44 days (95% CI 10.34, 10.55) for non-teaching hospitals compared to a mean of 12.47 (95% CI 12.34, 12.59) days in teaching hospitals. These indices changed significantly with the use of the condition specific index for both teaching and non-teaching hospitals. However, even with significantly greater adjustment than the Deyo, length of stay continued to be significantly greater among teaching hospitals 11.83 (95% CI 11.71, 11.93) than non-teaching hospitals 9.90 (95% CI 9.80, 10.00). The condition specific index significantly adjusted for total charges among teaching and non-teaching hospitals when compared to the Deyo. The mean total charges for those with perioperative spine infection were \$59,449.48 (95% CI \$58,579.71, \$60,319.25) among non-teaching hospitals compared to a mean of \$75,052.72 (95% CI \$ 74,130.97, \$75,974.47) in teaching hospitals. Among teaching hospitals there was a difference of \$4,986.17 between the Deyo Comorbidity Index and the condition specific index. Following adjustment with the condition specific index total charges continued to be significantly greater at teaching hospitals \$70,066.55 (95% CI \$69,183.89, \$70, 949.22) than non-teaching hospitals \$55,670.55 (95% CI \$ 54,821.34, \$56,519.77). The odds of death were 6.31 (95% CI 5.14, 7.73) among non-teaching hospitals and 5.39 (95% CI 4.68, 6.22) at teaching hospitals. The condition specific index adjusted significantly for 39.2% of the confounding in death among teaching hospitals reducing it to 3.44 (95% CI 2.97, 3.98).

Discussion

Our study endeavored to explore whether a condition specific index would lead to more specific mortality and morbidity adjustments than a commonly used comorbidity index and whether the underlying inherent differences between teaching and non-teaching facilities would be so substantial, that significant variations would exist even after the use of specific risk adjustment measures. The findings suggest that the condition specific index is more sensitive for adjusting mortality, morbidities and hospital disposition measures (such as length of stay and total charges) but is similar to the Deyo Comorbidity Index in adjusting for mortality for non-teaching hospitals. Interestingly, our condition specific measure adjusted significantly better for mortality in teaching hospitals and the adjusted estimate was similar to the non-teaching hospitals. This was substantially better than the Deyo Comorbidity Index a risk adjustment index originally designed with mortality as the outcome. Further, the comparative findings between teaching and non-teaching facilities were substantially dissimilar, even upon adjustment using a general (Deyo Comorbidity Index) adjustment measure and the condition specific index. Since consumers of government sponsored Internet sites rate hospital performance using measures such as mortality and morbidity, this finding is of concern, specifically since small variations in outcomes can affect rankings significantly¹⁶.

Risk adjustment measures have now been commonly used in outcomes research for over 2 Decades¹⁷. Although risk adjustment measures attempt to correct for case severity through statistical methods, the ability to adjust for comparable measures across institutions has been routinely criticized^{18–22}. It is known that no risk-adjustment approach can control for every factor affecting outcomes of care²⁰. Our findings reflect the significant variations in outcomes between teaching and non-teaching facilities; outcomes that still varied widely after adjustment using the Deyo Comorbidity Index and the condition specific index, especially among length of stay and total charges. This suggests that the significant differences in outcomes in patients who received spine surgery for decompression, disc repair, fusion, or other operative conditions are not limited to those associated with a provider but may be reflective of non-adjusted factors such as patients' physical and cognitive abilities, sensory and emotional factors, willingness to participate in care, and supportive environments²⁰.

The use of a condition specific comorbidity index for perioperative spine infection seems to make sense for several reasons. Firstly, a general comorbidity index such as the Deyo Comorbidity Index may lack sensitivity in identifying comorbidities that are reflective of a specific targeted condition. The Deyo Comorbidity Index includes 17 common comorbidities that influence mortality. In the condition specific index, comorbidities were targeted that were most reflective toward associated with spine infection that were not included in the Deyo Comorbidity Index. These included small prevalent findings of Malnutrition and Thrombophlebitis which had strong associations with perioperative spine infection. To our knowledge, the association of these comorbidities with perioperative spine infection has not been previously examined in the literature.

In situations in which the perioperative mortality is relatively low, such as spine surgery, measures that reflect morbidity, costs of care, and improved discharge status may be better indicators of a positive outcome¹. This is the case with this study where the period prevalence of mortality associated with perioperative spine surgery was low at 1.4%. Our study demonstrates that significant variations found between hospital disposition variables (length of stay and total charges) among the comparative indices. This suggests that the sensitivity of risk adjustment procedures may be more powerful for hospital disposition variables depending on teaching status, indicating that true variations across institutions may be more

accurately reflected only for these forms of outcomes. Further investigation is needed including use of functional outcome markers to better reflect morbidity.

Limitations

We recognize several limitations to this analysis related to study design, differences in hospital teaching status and use of large administrative databases. This analysis was cross sectional in nature and cross sectional data limits the ability to draw causal inferences from our estimates. However, the purpose was to design an index to adjust for confounding specific to perioperative spine infection and not the determination of causation for perioperative spine infection. This is can be the first step in the process of designing a risk adjustment index and a longitudinal study, such as conducted in the Medicare Database, would serve well to validate this scale and determine if this condition specific index will predict hospital disposition characteristics and if differences in teaching hospital status are also observed.

The use of large administrative databases such as the NIS can provide insight into rare conditions and use of healthcare services, such as in the case with perioperative spine infection, however there are several limitations to its use. First, our means of classifying subjects into the main exposure was indirect as there are no ICD-9 codes specific to perioperative spine infection. Our inclusion criteria included a litany of surgical spine procedures and we further developed our exposure with specific post operative infection ICD-9 codes, including codes that may be used to indicate perioperative spine infection. Therefore our findings should be interpreted with caution as there is the risk of misclassification of perioperative spine infection events. Second, the NIS provides data on in-patient discharge ICD-9 codes only and does not include outpatient follow-up or identify a patient with multiple inpatient admissions. Perioperative spine infection may not develop until days following discharge from an inpatient stay. Based upon the coding of discharge summaries in the NIS these readmissions for perioperative spine infection may not be included in our study. Therefore, the interpretation of our study may be more generalizable to perioperative spine infection events during inpatient stays following surgical procedures and may under represent a readmission event for infection. In addition, use of the NIS data should be viewed at the event level rather than the patient level. Lastly, there may be reasons beyond inherent differences between teaching and non-teaching hospitals to explain our results. Within the NIS we are unable to account for events such as a patient with multiple trauma, events such as this may be more likely to be seen at larger teaching hospitals. There is also the risk that the differences between teaching and non-teaching facilities are associated with differences in quality of care, system issues, and/or environment components. We recognize these as limitations that may affect the results of our study in determining differences between teaching and non-teaching hospitals but cannot control for these elements in this study.

Conclusion

Risk adjustment measures are a popular means to adjust for confounding for many comorbidities associated with complex diseases in inpatient stays. This condition specific comorbidity index appears to adjust for routine hospital discharge and total hospital charges significantly better than a commonly used adjustment measure. Furthermore, it demonstrated to be as good at adjusting for other individual and hospital disposition characteristics such as death and length of stay depending on the teaching status of the hospital. This information suggests that condition specific comorbidity adjustment index may be useful for perioperative spine infection.

- Condition specific measures may be more useful when morbidity is of question.

- Condition specific measures may be more sensitive when assessing hospital disposition characteristics related to perioperative spine infection.
- There may be inherent differences in hospital disposition characteristics of perioperative spine infection across teaching and non-teaching hospitals after adjustment for comorbidities.

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Appendix A

Confounders associated with perioperative spinal infection with an odds ratio of 1.2 – 2.5

Cerebrovascular Disease

[430–438] Cerebrovascular disease

Hypo or Hyper Calcium

[275.42] Hypercalcemia

[275.41] Hypocalcemia

Peripheral Vascular Disease

[443.9] Peripheral vascular disease, includes intermittent claudication

[441–441.9] Aortic aneurysm

[785.4] Gangrene

Fracture

[800–804] Fracture of skull

[805–809] Fracture of neck and trunk

[810–819] Fracture of upper limb

[820–829] Fracture of lower limb

Hypo or Hyper Thyroidism

[252.0] Hyperparathyroidism

[252.1] Hypoparathyroidism

Confounders associated with perioperative spinal infection with an odds ratio of 2.5 – 3.5

Congestive Heart Failure

[428–428.9] Heart Failure

Dementia

[290–290.9] Senile and pre-senile dementia

Mild liver disease

[571.2] Alcoholic cirrhosis

[571.5] Cirrhosis without mention of alcohol

[571.6] Biliary cirrhosis
 [571.4–571.49] Chronic hepatitis
 Rheumatologic Disease
 [710.0] Systemic lupus erythematosus
 [710.1] Systemic sclerosis
 [710.4] Polymyositis
 [714.0–714.2] Adult rheumatoid arthritis
 [714.81] Rheumatoid lung
 [725] Polymyalgia rheumatica
 Any malignancy, including leukemia and lymphoma
 [140–172.9] Malignant neoplasms
 [174–195.8] Malignant neoplasms
 [200–208.9] Leukemia and lymphoma
 Renal Disease
 [582–582.9] Chronic glomerulonephritis
 [583–583.7] Nephritis and nephropathy
 [585] Chronic renal failure
 [586] Renal failure, unspecified
 [588–588.9] Disorders resulting from impaired renal function
 Moderate or severe liver disease
 [572.2–572.8] Hepatic coma, portal hypertension, other sequelae of chronic liver disease
 [456.0–456.21] Esophageal varices
 Alcoholism
 [303.00 –303.93]
 Peptic Ulcer disease
 [531–534.9] Gastric duodenal and gastrojejunal ulcers
 Scar
 [709.2] Scar conditions and fibrosis of skin
 [701.4] Keloid scar
 Burns
 [940 – 949] Burns
 Diabetes with chronic complications
 [250.4–250.6] Diabetes with renal, ophthalmic, or neurological manifestations

Confounders associated with perioperative spinal infection with an odds ratio of 3.5 – 4.5

Venous embolism and thrombosis of unspecified deep vessels of lower extremity
 [453.40]
 Metastatic solid tumor
 [196–199.1] Secondary malignant neoplasm of lymph nodes and other organs
 Dehydration
 [276.51]

Confounders associated with perioperative spinal infection with an odds ratio of 4.5 – 5.5

Hemiplegia or paraplegia

[344.1] Paraplegia

[342–342.9] Hemiplegia

Confounders associated with perioperative spinal infection with an odds ratio of 5.5 – 6.5

Thrombophlebitis

[451.2] Phlebitis and thrombophlebitis of lower extremities, unspecified

[451.8] phlebitis and thrombophlebitis of other sites

[997.2] peripheral vascular complications, other

[451.19] phlebitis and thrombophlebitis of other

[451.11] phlebitis and thrombophlebitis of femoral vein deep or superficial.

Confounders associated with perioperative spinal infection with an odds ratio of 6.5 – 7.5

Malnutrition

[263.0] Malnutrition of moderate degree

[263.1] Malnutrition of mild degree

Table 1

Beta Coefficients, p-values and proportions of diagnosis to determine significance of potential confounders with perioperative spine infection.

Covariate	n	%	Beta coefficient	p-value
Congestive Heart Failure	719	3.01	0.8776291	<0.0001
Peripheral Vascular Disease	271	1.14	0.2299316	<0.0001
Cerebrovascular Disease	242	1.01	0.3043727	<0.0001
Dementia	25	0.10	0.9041671	<0.0001
Rheumatic Disease	476	2.00	0.4382815	<0.0001
Peptic Ulcer	210	0.88	0.5006272	<0.0001
Mild Liver Disease	80	0.34	0.4337626	0.001
Chronic Diabetes	2,600	10.90	0.1631093	<0.0001
Hemiplegia	449	1.88	1.405236	<0.0001
Renal Disease	65	0.27	0.8307755	<0.0001
Any Malignancy	543	2.28	0.4424129	<0.0001
Moderate Liver Disease	25	0.10	0.7363187	0.002
Metastasis	474	1.99	0.575741	<0.0001
Thrombophlebitis	128	0.54	1.718162	<0.0001
Fracture	890	3.73	0.2739547	<0.0001
Alcoholism	163	0.68	0.6405916	<0.0001
Scar	73	0.31	0.7268284	<0.0001
DVT	102	0.43	0.9556666	<0.0001
Burns	14	0.06	0.7505649	0.007
Hyper or Hypo Calcium	56	0.23	0.2301472	0.095
Hyper or Hypo Thyroidism	14	0.06	0.8056077	0.004
Dehydration	95	0.40	1.188497	<0.0001
Malnutrition	46	0.19	1.981846	<0.0001

Table 2

Characteristics of subjects with perioperative spine infection from the NIS database.

Characteristic	n (%) [*]
Male	11,834 (49.6)
Female	12,005 (50.4)
Mean age	51.2 (SD 15.2)
Race	
Caucasian	15,065 (82.2)
African American	1,614 (8.8)
Hispanic	1,058 (5.8)
Asian or Pacific Islander	133 (0.7)
Native American	67 (0.4)
Other	400 (2.2)
Insurance	
Medicare	7,098 (29.8)
Medicaid	2,227 (9.4)
Private	10,284 (43.2)
Self Pay	636 (2.7)
Income	
\$1–34,999	8,522 (37.8)
\$35,000–44,999	5,523 (24.5)
45,000 or more	8,524 (37.8)

* with perioperative spine infection

Table 3

Logistic regression of perioperative spine infection with mortality and hospital disposition variables as the outcome. A comparison between the crude and adjusted odds ratio's with the Deyo and condition specific adjustment index.

Variable (Sample Size)	Crude (95% CI)	Deyo (95% CI)	Change*	Condition Specific (95% CI)	Change*	p-value
Routine Discharge (n=1,206,395)	0.22 (0.22, 0.23)	0.24 (0.23, 0.24)	3.3%	0.24 (0.23, 0.25)	3.7%	0.43
Death (n=1,210,672)	5.83 (5.19, 6.54)	5.38 (4.78, 6.05)	8.0%	3.53 (3.14, 3.97)	50.0%	<0.001
Length of Stay [†] (n=1,211,470)	11.48 (11.40, 11.56)	11.27 (11.20, 11.35)	0.21 days	10.86 (10.79, 10.94)	0.62 days	<0.001
Total Charges [‡] (n=1,189,513)	\$67245.88 (\$66,629.6, \$67,862.15)	\$65,761.71 (\$65,151.66, \$66,371.76)	\$1,484.20	\$62,710.75 (\$62,116.04, \$63,305.47)	\$4,535.13	<0.001

* Change calculated with a change in estimate formula (calculated as |ln adjusted OR – ln crude OR|) or subtraction of mean days and dollars. Used to quantify the amount of confounding between the crude and adjusted estimates. Change based on unrounded estimates.

[†] Linear regression estimates of means for length of stay in days and total charges in US dollars.

p-value for difference between the betas or mean values of the Deyo compared to the condition specific odds ratio or mean.

Table 4

Logistic regression of perioperative spine infection and mortality and hospital disposition variables as the outcome. Difference between crude and adjusted odds ratios with the Devo and condition specific adjustment index among non-teaching hospitals.

Variable (Sample Size)	Crude (95% CI)	Devo (95% CI)	Change [*]	Condition Specific (95% CI)	Change [*]	p-value
Routine Discharge (n=549,581)	0.23 (0.22, 0.24)	0.25 (0.24, 0.26)	7.1%	0.25 (0.24, 0.26)	8.3%	0.54
Death (n=551,104)	6.31 (5.14, 7.73)	3.92 (3.18, 4.83)	47.5%	3.61 (2.93, 4.45)	55.7%	0.29
Length of Stay [†] (n=551,592)	10.44 (10.34, 10.55)	10.22 (10.12, 10.33)	0.22 days	9.90 (9.80, 10.00)	0.54 days	<0.001
Total Charges [‡] (n= 543,314)	\$59,449.48 (\$58,579.71 \$60,319.25)	\$57,995.79 (\$57,133.02 \$58,858.55)	\$1,453.69	\$55,670.55 (\$54,821.34 \$56,519.77)	\$3,777.93	<0.001

^{*} Change calculated with a change in estimate formula (calculated as |ln adjusted OR – ln crude OR|) or subtraction of mean days and dollars. Used to quantify the amount of confounding between the crude and adjusted estimates.

[†] Linear regression estimates of means for length of stay in days and total charges in US dollars.

[‡] p-value for difference between the betas or mean values of the Devo compared to the condition specific odds ratio or mean.

Table 5

Logistic regression of perioperative spine infection with mortality and hospital disposition variables as the outcome. Difference between crude and adjusted odds ratio's with the Deyo and condition specific adjustment index among teaching hospitals.

Variable (Sample Size)	Crude (95% CI)	Deyo (95% CI)	Change*	Condition Specific (95% CI)	Change*	p-value
Routine Discharge (n=596,201)	0.22 (0.21, 0.23)	0.23 (0.22, 0.23)	2.2%	0.23 (0.23, 0.24)	5.5%	0.10
Death (n=598,808)	5.39 (4.68, 6.22)	5.10 (4.41, 5.90)	5.7%	3.44 (2.97, 3.98)	39.2%	<0.001
Length of Stay [†] (n= 599,101)	12.47 (12.34, 12.59)	12.28 (12.16, 12.39)	0.20 days	11.82 (11.71, 11.93)	0.66 days	<0.001
Total Charges [‡] (n= 586,300)	\$75,052.72 (\$74,130.97 \$75,974.47)	\$73,578.09 (\$72,666.63 \$74,489.55)	\$1474.63	\$70,066.55 (\$69,183.89 \$70,949.22)	\$4,986.17	<0.001

* Change calculated with a change in estimate formula (calculated as |ln adjusted OR – ln crude OR|) or subtraction of mean days and dollars. Used to quantify the amount of confounding between the crude and adjusted estimates.

[†] Linear regression estimates of means for length of stay in days and total charges in US dollars.

p-value for difference between the betas or mean values of the Deyo compared to the condition specific odds ratio or mean.