Rates of Mortality in Cervical Spine Surgical Procedures and Factors Associated With Its Occurrence Over a 10-Year Period: A Study of 342 477 Patients on the Nationwide Inpatient Sample

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Rates of Mortality in Cervical Spine Surgical Procedures and Factors Associated With Its Occurrence Over a 10-Year Period: A Study of 342 477 Patients on the Nationwide Inpatient Sample

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ABSTRACT

Background: Risk of death is important in counseling patients and improving quality of care. Incidence of death in cervical surgery is not firmly established due to its rarity and limited sample sizes, particularly in the context of different surgeries, demographics, and risk factors. Particularly, different patient risk profiles may have varying degrees of risk in terms of surgeries, comorbidities, and demographics. This study aims to use a large patient cohort available on a national database to study the prevalence of death associated with cervical spine surgery.

Methods: This study was a retrospective review of the Nationwide Inpatient Sample (NIS) years 2003–2012. A total of 342 477 patients were identified by *International Classification of Diseases, Ninth Revision, Clinical Modification* codes undergoing spinal fusion or decompression for disc degeneration, stenosis, spondylosis, myelopathy, postlaminectomy syndrome, scoliosis, or neck pain associated with the cervical region. Patients with malignancy were excluded from analysis. Incidence of mortality was assessed by χ^2 tests across different patient demographics and comorbidities, procedures performed, and concurrent in-hospital complications. Binary logistic regression identified significant increases or decreases in risk of death while controlling for comorbidities, race, sex, and Mirza invasiveness. Significance was defined as $P < .05$ differences relative to overall cohort.

Results: The study analyzed 342 477 patients with an overall mortality rate of 0.32%. A total of 231 977 simple fusions (single approach and <3 levels) experienced a mortality rate of 0.256%; 49 594 complex fusions (combined approach or ≥3 levels) had a mortality rate of 0.534%; and 61 285 decompression-only procedures reported a 0.424% mortality rate, all $P < .001$ from overall rate. In reporting rates across different demographics, male patients experienced a significantly higher risk for mortality (odds ratio [OR], 2.16; 95% CI, 1.87–4.49), as did black patients (OR, 1.58; CI, 1.32–1.90) and patients over age 75 (OR, 7.55; 95% CI, 6.58–8.65), all $P < .001$. Patients with liver disease reported 6.40% mortality. Similarly, patients with congestive heart failure (3.91%), cerebrovascular disease (3.41%), and paraplegia (3.79%) experienced high mortality rates, all in cohorts of over 2000 patients, all $P < .001$. Concurrent in-hospital complications with the highest risk of mortality were shock (OR, 51.41; 95% CI, 24.08–109.76), pulmonary embolism (OR, 25.01; 95% CI, 14.70–42.56), and adult respiratory distress disorder (OR, 14.94; 95% CI, 12.75–17.52), all $P < .001$.

Conclusion: In 342 477 cervical spine surgery patients an overall mortality rate of 0.32% was reported. The rate was 3.91% in a cohort of 5933 patients with congestive heart failure and 3.79% in a cohort of 6947 patients with paraplegia. These findings are consistent with previous estimates and may help counsel patients and improve in-hospital safety.

Level of Evidence: 3

Cervical Spine

Keywords: cervical surgery, mortality, cervical fusion

INTRODUCTION

The risk of mortality is a rare but devastating occurrence for patients undergoing elective spinal surgical procedures. The reported mortality rate in cervical spine surgery based on currently available literature[1–5] ranges from 0.14% to 1.53%. With the increasing age of the population and subsequent rise in demand for procedures being performed each year,[6,7] further investigation is warranted to better identify patients at risk for mortality.

Smith et al.[8] identified major causes of mortality in spinal deformity correction surgeries as respira-

tory failure, cardiac compromise, and sepsis, accounting for 159 of the 197 deaths in the study. This study did not include patients with malignancy, which account for a significant proportion of mortalities in cervical spine surgery.[5,9] Risk of these events causing mortality may be elevated in spine surgeries due to their longer operative times and hemodynamic shifts.[10] The overall strength of evidence in establishing mortality and morbidity based on existing literature on the cervical spine is low.[11,12] Capturing true mortality rates among cervical spinal surgeries may be difficult given their uncommon occurrence with individual surgeons and institutions.

There are a number of individual studies looking at perioperative mortality in a wide range of sample populations, but they focus on analyzing data surrounding specific cervical spine pathologies or procedures.[1,13–16] Larger studies have looked at epidemiologic trends in cervical spine procedures including surgical volume, patient demographics, costs, and/or length of hospitalization.[1,6,7,17,18] Recent literature that specifically evaluates mortality in the cervical spine is limited. The purpose of this study, therefore, is to establish rates of mortality in cervical spine surgery according to procedure type, patient comorbidities, and complications experienced and to determine risk factors for their development. Use of a large national database, such as the National Inpatient Sample (NIS), will allow capture of nationwide trends of this uncommon occurrence.

METHODS

Data Source

The NIS is a database developed for the Healthcare Cost and Utilization Project (HCUP) and is the largest publicly available, all-payer inpatient health care database in the United States. It draws from nearly 8 million hospital stays each year and is designed to provide an approximated 20% stratified sample of participating community hospitals. The states participating in the NIS are estimated to represent more than 97% of the US population.[19] For each discharged patient, the NIS provides data elements including primary and secondary diagnoses and procedures in *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) format, patient demographics, total charges, length of stay, and comorbidity measures. To improve representation, national estimates are generated using discharge weight files. More detailed information is available at https://www.hcup-us.ahrq.gov/nisoverview.jsp.[20]

Inclusion and Exclusion Criteria

A retrospective review of the NIS database years 2003 through 2012 was performed. Patients included were age 18 years and over and, identified by *ICD-9* coding, undergoing cervical fusion (81.00, 81.30, 81.39, 81.04-81.08, 81.34-81.38, 81.61-81.64), laminectomy (03.02), discectomy (80.50, 80.51), or other decompression (03.09). Included patients were treated for disc degeneration, stenosis, spondylosis, myelopathy, postlaminectomy syndrome, scoliosis, or neck pain (Appendix A).

Mortality Predictors

Procedures were classified as simple spinal fusions (anterior [81.01, 81.02, 81.34, 81.36, 81.37] or posterior approach [81.03, 81.33] less than 3 levels), complex fusions (involving 3 or more levels [81.61, 81.63, 81.64] or a combined approach), or decompression-only procedures (03.09, 03.02, 80.50, 80.51). Interbody device use (84.51) and bone morphogenic proteins (BMP; 84.52) were also assessed. Demographics were stratified by age (18–40, 41–54, 55–64, 65–74, and 75+ years), gender, and race (white, black, Asian, or other). Inpatient comorbidities were assessed using established protocol to construct the Charlson Comorbidity Index by *ICD-9-CM* coding.[21] Next, concurrent complications (Appendix B) and diagnoses (Appendix A) were analyzed as predictors.

Statistical Analysis

Incidence of mortality was analyzed according to procedure, demographics, inpatient complications, and patient comorbidities using HCUP-provided hospital and year adjusted weights. Analysis of variance linear trends analysis described changes in mortality over the years studied. Predictors were transformed into categorical values to facilitate analysis to establish clinically relevant relative risk. After establishing incidence, binary logistic regression analyzed predictors independent contribution to risk of death controlling for race, Charlson Comorbidity Index, gender, age, and procedure performed. Predictors were removed from the list of controls when analyzed as an independent risk

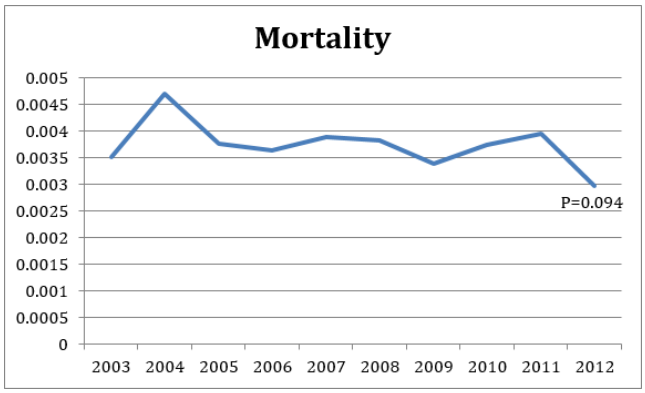

Figure. Changes in mortality incidence between the years 2003 and 2012.

factor. Significance was set at $P < .05$. IBM SPSS Statistics version 23.0 (IBM Corp, Armonk, New York) was used to perform all descriptive and comparative statistics. Odds ratios are reported as OR (95% CI).

RESULTS

A total of 342 477 patients age 18 or older undergoing cervical spine procedures from 2003 through 2012 were identified in the NIS database (average age = 53.05 years, female = 51%, male = 49%); 1109 deaths were found (0.32% mortality). There was no significantly increasing or decreasing mortality trend across the decade studied ($P = .094$; Figure).

Demographics

Male patients experienced significantly higher mortality (0.467%) than women (0.182%) (OR, 2.16 [95% CI, 1.87–4.49]; Table 1). Black race was an independent risk factor for mortality (OR, 1.58 [95% CI, 1.32–1.90]), whereas white race demonstrated a protective effect (OR, 0.75 [95% CI, 0.67–0.85]). Patients over age 75 experienced 2.35% mortality (OR, 7.55 [95% CI, 6.58–8.65]).

Table 1. Rates of mortality stratified on type of demographics.

	n	No. of Deaths	Mortality, %	OR (95% CI)
Overall	342 477	1109	0.32	
Gender				
Male	170 768	798	0.47	2.16 (1.87–4.49)
Female	171 273	311	0.18	0.46 (0.40–0.53)
Race				
White	220 082	674	0.31	0.75 (0.67–0.85)
Black	25 991	127	0.49	1.58 (1.32–1.90)
Asian	14 163	58	0.41	1.06 (0.81–1.40)
Other	82 241	250	0.30	1.15 (0.99–1.32)
Age				
18–40	47 407	62	0.13	0.56 (0.43–0.73)
41–54	146 388	149	0.10	0.28 (0.23–0.34)
55–64	79 021	186	0.24	0.65 (0.55–0.76)
65–74	46 432	213	0.46	1.10 (0.93–1.29)
75+	21 220	498	2.35	7.55 (6.58–8.65)

Abbreviation: OR, odds ratio.

Table 2. Rates of mortality stratified on type of procedure.

Procedure	n	No. of Deaths	Mortality, %	OR (95% CI)
Simple fusion	231 977	594	0.26	0.63 (0.55–0.72)
Anterior	215 404	467	0.22	0.58 (0.51–0.66)
Posterior	2042	0	0.00	NA
Complex fusion	49 594	265	0.53	1.10 (0.95–1.28)
Anterior	35 684	158	0.44	1.07 (0.9–1.28)
Posterior	1050	0		
Combined	722	6	0.83	1.34 (0.49–3.87)
Decompression only	61 285	260	0.42	0.59 (0.47–0.74)
Interbody device	133 433	305	0.23	0.63 (0.55–0.73)
BMP	24 192	114	0.47	1.28 (1.04–1.57)

Abbreviation: BMP, bone morphogenic proteins; OR, odds ratio.

Procedure and Complication

Stratification by procedure type is shown in Table 2. The mortality rate in simple fusions was 0.256% (OR, 0.63 [95% CI, 0.55–0.72]), and in complex fusions 0.534% (OR, 1.10 [95% CI, 0.95–1.28]). Decompression-only procedures were associated with an elevated mortality rate (0.424%) but lower risk after adjustment for confounders (OR, 0.59 [95% CI, 0.47–0.74]). Use of an interbody device or BMP to achieve spinal fusion was associated with a mortality rate of 0.229% (OR, 0.63 [95% CI, 0.55–0.73]) and 0.471% (OR, 1.28 [95% CI, 1.04–1.57]), respectively.

Table 3. Rates of mortality stratified on type of complications.

Procedure	n	No. of Deaths	Mortality, %	OR (95% CI)
Dysphagea	3245	28	0.86	1.63 (1.10–2.42)
Nervous System	1163	60	5.16	9.72 (7.07–13.36)
Cardiac comp	1349	92	6.82	7.70 (5.86–10.11)
PVD	91	3	3.30	6.67 (2.29–19.38)
Respiratory	1416	46	3.25	3.77 (2.62–5.44)
Digestive	744	9	1.21	2.00 (0.87–4.55)
Urinary	1454	12	0.83	1.06 (0.52–2.18)
Device	8834	14	0.16	0.66 (0.40–1.08)
Shock	55	15	27.27	51.41 (24.08–109.76)
Hematoma	1906	47	2.47	4.10 (2.91–5.77)
Puncture	1172	14	1.19	3.18 (1.82–5.57)
Infection	724	23	3.18	2.94 (1.56–5.16)
Anemia	4830	99	2.05	1.36 (1.06–1.74)
ARDS	3799	304	8.00	14.94 (12.75–17.52)
PE	165	23	13.94	25.01 (14.70–42.56)
DVT	839	53	6.32	8.27 (5.98–11.44)

Abbreviation: PVD, peripheral vascular disease; ARDS, acute respiratory distress syndrome; PE, pulmonary embolism; DVT, deep vein thrombosis.

Table 4. Rates of mortality stratified on type of comorbidities.

	n	No. of Deaths	Mortality, %	OR (95% CI)
Previous myocardial infarction	9189	135	1.47	2.17 (1.77–2.66)
Congestive heart failure	5933	232	3.91	3.86 (3.23–4.62)
Peripheral vascular disease	4069	51	1.25	1.17 (0.84–0.63)
Cerebrovascular disease	3867	132	3.41	4.09 (3.28–5.09)
Dementia	502	15	2.99	2.12 (1.24–3.63)
Chronic pulmonary disease	48 000	189	0.39	0.99 (0.83–1.18)
Rheumatic disease	7361	20	0.27	0.70 (0.44–1.12)
Peptic ulcer disease	1505	12	0.80	1.32 (0.67–2.63)
Mild liver disease	2356	42	1.78	4.05 (2.90–5.64)
Diabetes without chronic complication	44 780	179	0.40	0.72 (0.60–0.87)
Diabetes with chronic complication	3760	39	1.04	1.45 (1.01–2.08)
Hemiplegia or paraplegia	6957	264	3.79	6.59 (5.57–7.79)
Renal disease	8964	208	2.32	2.86 (2.40–3.41)
Moderate or severe liver disease	172	11	6.40	8.44 (4.44–16.04)
Any malignancy	1177	87	7.39	1.17 (0.88–1.56)
Metastatic solid tumor	1081	96	8.88	4.38 (3.34–5.69)

Abbreviation: OR, odds ratio.

Complications

In-hospital complications associated with the highest mortality risk (see Table 3) were shock (OR, 51.41 [95% CI, 24.08–109.76]), pulmonary embolism (OR, 25.01 [95% CI, 14.70–42.56]), and acute respiratory distress syndrome (OR, 14.94 [95% CI, 12.75–17.52]). Other complications associated with significant risk of mortality included cardiac compromise, deep vein thrombosis, nervous system disorders, respiratory complications, and infection.

Comorbidities

Comorbidities were designated as defined by the Charlson/Deyo clinical comorbidity index.[22] Those linked with significantly higher mortality included moderate to severe liver disease (OR, 8.44 [95% CI, 4.44–16.04]), congestive heart failure (OR, 3.86 [95% CI, 3.23–4.62]), paraplegia (OR, 6.59 [95% CI, 5.57–7.79]), cerebrovascular disease (OR, 4.09 [95% CI, 3.28–5.09]), and renal disease (OR, 2.86 [95% CI, 2.40–3.41]; see Table 4). Other comorbidities include history of acute or chronic myocardial infarction (OR, 2.17 [95% CI, 1.77–2.66]), diabetes with chronic complication (OR, 1.45 [95% CI, 1.01–2.08]), and peripheral vascular disease (OR, 1.17 [95% CI, 0.84–0.63]).

Table 5. Rates of mortality stratified by spine diagnosis.

	n	No. of Deaths	Mortality, %	OR (95% CI)
Disc displacement	245 589	295	0.12	0.24 (0.20–0.27)
Disc degeneration	44 533	35	0.08	0.30 (0.21–43)
Stenosis	34 197	71	0.21	0.43 (0.33–0.57)
Spondylolisthesis	124 585	284	0.23	0.41 (0.35–0.48)
Fracture	9738	207	2.13	3.44 (2.84–4.26)
Scoliosis	8868	39	0.44	1.10 (0.78–0.154)
Cord injury	3652	97	2.66	3.52 (2.73–4.53)
Myelopathy	87 397	339	0.39	1.61 (1.39–1.87)
Kyphosis	6113	28	0.46	1.09 (0.73–1.34)

Abbreviation: OR, odds ratio.

Diagnoses

Risk of mortality was higher in treating certain diagnoses, which were established by querying the primary diagnosis (Table 5). Fracture (OR, 3.44 [95% CI, 2.84–4.26]), cord injuries (OR, 3.52 [95% CI, 2.73–4.53]), and myelopathy (OR, 1.61 [95% CI, 1.39–1.87]) diagnoses displayed increased risk. However, neither scoliosis (OR, 1.10 [95% CI, 0.78–1.54]) nor kyphosis (OR, 1.09 [95% CI, 0.73–1.34]) was a risk factor for mortality.

DISCUSSION

Despite the low incidence of mortality involved with spine surgery, it is important to be able to identify patients at increased risk for the ultimate adverse occurrence prior to making a decision to proceed with surgery. An understanding of where mortality occurs in cervical spine surgery can help practitioners evaluate current practices and find ways to better optimize patients before surgery.

The incidence of mortality in this study (0.32%) is consistent with existing literature on cervical spine surgery. Wang et al.[1] found a mortality rate of 0.14% in a nationwide database study from 1992 to 2001 of patients with degenerative cervical spine disease. The lower rate may be explained by the younger patients in the study, with only 13% of the cohort being 65 years of age or older, as well as the use of stricter exclusion criteria. In a more recent study by Skolasky et al.,[2] the mortality rate in all

cervical spine procedures between 2000 and 2009 was found to be 0.42%. This, along with the current analysis, may be more reflections of true mortality based on their inclusion of patients with malignancy.

Our findings are also consistent with the results of large systematic reviews that looked at spine surgery as a whole. Dekutoski et al.[12] compiled data from 11 studies and found surgeries involving the cervical or lumbar spine were associated with mortality rates <1%. Thoracic spine surgery, however, had a considerably higher mortality rate ranging from 3% to 7%.[12] This may be explained by the higher incidence of complications, particularly pulmonary, associated with thoracic surgeries and their proximity to vital structures.[23] A recent single-institution study[5] with access to surgical details, which are not available in the NIS, found operations of the cervical spine to be a significant predictor of postoperative mortality. This study, however, did not find an increased risk of mortality with thoracic procedures, but attributed this to low power from a small sample of cases involving the thoracic spine.[5]

Prior studies have looked at mortality based on specific spinal procedures. Anterior cervical fusions account for approximately 80% of the total cervical spine procedures performed annually in the United States.[7] Memtsoudis et al.[14] examined noncervical spinal fusions and mortality based on approach and found higher rates with anterior and combined anterior/posterior spinal fusions. Our study found consistent results, with the combined approach being associated with the highest procedure-derived mortality rate at 0.83%. Despite the use of a national database, the sample size for posterior approaches in this study did not have sufficient power to establish a decreased risk for mortality. Our findings regarding mortality risk associated with procedures must be interpreted within that context.

Literature detailing BMP's effect in the cervical spine has not found a significant increase in mortality with BMP use.[24,25] The current study found it as an independent risk factor by a slim margin, which may represent more invasive surgeries that were not adequately controlled in multivariate analysis.

To our knowledge, patient age may be the most scrutinized aspect of patient demographics in literature about outcomes in spinal surgery. Increased age has been identified[1,3,5,8] as an independent predictor of mortality in various studies involving pathology and procedures of the spine. This is supported by our results, which reveal that an increase in mortality risk with male sex in our analysis was also associated with significantly increased risk of mortality following cervical spine surgery. Schoenfeld et al.[17] examined effect of gender in spine surgery and found that males had a 63% increase in postoperative odds of death compared with females. However, 5 of the 11 studies included were based on the lumbar spine, whereas another 5 looked at spine surgery in general. Skolasky et al.[2] examined the impact of race on outcomes after cervical spine surgery, and our results support their findings of blacks being at increased risk of death (after adjusting for confounders). The etiology for these findings is thought to be multifactorial[2] and should be a focus for future research because it is not within the scope of this database to establish causality.

Desai et al.[5] performed a study examining independent predictors of mortality following spine surgery and found increased age and cervical location to be prognostic indicators of 30-day postoperative mortality. Demographics were not identified as an independent predictor in their findings. However, the study was based on single-institution data and the generalizability of their results was limited.[5] The results of our study also found black race to be associated with an increased risk of mortality, consistent with the findings of Skolasky et al.[2] This was postulated to be a result of patients presenting at later clinical stages or with more comorbidities. Our findings also indicated that male sex was associated with increased mortality rates.

The limitations of this study arise primarily from the design of the NIS database used for our analysis. Though we were able to comprehensively capture mortality rates, the study does not address morbidity associated with cervical spine surgery. Events such as wound complications, neurologic deficits, or postoperative neuropathic pain may lead to readmission and are important when considering the longitudinal nature of many cervical disease processes. Procedure type was used as a surrogate for case complexity, but the database limits us from further detailing the surgical procedure (ie, blood loss, length of surgery, individual case complexity, preoperative American Society of Anesthesiologists grade). In addition, patient comorbidities are not

fully specified (eg, severity, length of disease, patient medication compliance). Last, the severity of complications is not quantified; we are aware of the end point only if it involved mortality. This study cannot be generalized to all cervical spine surgeries because it does not include cases involving malignancy. The NIS database design also prevents the capture of mortality rates for outpatient cervical spine procedures, which are being performed with increasing frequency.[26] It may underestimate overall mortality for this reason[1,9] but is likely accurate in the context of elective cervical procedures.

CONCLUSION

Having realistic expectations of the anticipated outcome of a procedure is beneficial to both the physician and patient in the decision-making process. This study looked at 342 477 cervical spine surgery patients and found an overall mortality rate of 0.32%. Characteristics that place patients at increased risk of mortality include increased age, male sex, and black race. Patient comorbidities that may require careful preoperative evaluation and optimization are moderate to severe liver disease, congestive heart failure, and paraplegia. Complications of cervical spine surgery associated with high risk of mortality were shock and pulmonary embolism. Further research is required to establish causation, but these precursory findings can help surgeons determine risk prognosis and counsel patients who are considering surgical intervention.

REFERENCES

1. Wang MC, Chan L, Mainman D, Kreuter W, Deyo RRA, Maiman DJ. Complications and mortality associated with cervical spine surgery for degenerative disease in the United States. *Spine Phila Pa 1976*. 2007;32(3):342–347.

2. Skolasky RL, Thorpe RJ, Wegener ST, Riley LH. Complications and mortality in cervical spine surgery: racial differences. *Spine (Phila Pa 1976)*. 2014;39(18):1506–1512.

3. Jalai CM, Worley N, Marascalchi BJ, et al. The impact of advanced age on peri-operative outcomes in the surgical treatment of cervical spondylotic myelopathy. *Spine (Phila Pa 1976)*. 2016;41(3):E139–E147.

4. Fineberg SJ, Oglesby M, Patel AA, Singh K. Incidence and mortality of perioperative cardiac events in cervical spine surgery. *Spine (Phila Pa 1976)*. 2013;38(15):1268–1274.

5. Desai R, Nayar G, Suresh V, et al. Independent predictors of mortality following spine surgery. *J Clin Neurosci*. 2016;29:100–105.

6. Marquez-Lara A, Nandyala SV, Fineberg SJ, Singh K. Current trends in demographics, practice, and in-hospital outcomes in cervical spine surgery. *Spine (Phila Pa 1976)*. 2014;39(6):476–481.

7. Oglesby M, Fineberg SJ, Patel AA, Pelton MA, Singh K. Epidemiological trends in cervical spine surgery for degenerative diseases between 2002 and 2009. *Epidemiol Spine*. 2013;38(14):1226–1232.

8. Smith JS, Saulle D, Chen C-J, et al. Rates and causes of mortality associated with spine surgery based on 108,419 procedures: a review of the Scoliosis Research Society Morbidity and Mortality Database. *Spine (Phila Pa 1976)*. 2012;37(23):1975–1982.

9. Zeidman SM, Ducker TB, Raycroft J. Trends and complications in cervical spine surgery: 1989-1993. *J Spinal Disord*. 1997;10(6):523–526.

10. Carabini LM, Zeeni C, Moreland NC, et al. Predicting major adverse cardiac events in spine fusion patients: is the revised cardiac risk index sufficient? *Spine (Phila Pa 1976)*. 2014;39(17):1441–1448.

11. Atkins D, Best D, Briss PA, et al. Grading quality of evidence and strength of recommendations. *BMJ*. 2004;328(7454):1490.

12. Dekutoski MB, Norvell DC, Dettori JR, Fehlings MG, Chapman JR. Surgeon perceptions and reported complications in spine surgery. *Spine (Phila Pa 1976)*. 2010;35(9 suppl):S9–S21.

13. Memtsoudis SG, Hughes A, Ma Y, Chiu YL, Sama AA, Girardi FP. Increased in-hospital complications after primary posterior versus primary anterior cervical fusion. *Clin Orthop Relat Res*. 2011;469(3):649–657.

14. Memtsoudis SG, Vougioukas VI, Ma Y, Gaber-Baylis LK, Girardi FP. Perioperative morbidity and mortality after anterior, posterior, and anterior/posterior spine fusion surgery. *Spine (Phila Pa 1976)*. 2011;36(22):1867–1877.

15. Williams BJ, Smith JS, Fu K-MG, et al. Does bone morphogenetic protein increase the incidence of perioperative complicationsin spinal fusion? *Spine (Phila Pa 1976)*. 2011;36(20):1685–1691.

16. Fineberg SJ, Ahmadinia K, Oglesby M, Patel AA, Singh K. Hospital outcomes and complications of anterior and posterior cervical fusion with bone morphogenetic protein. *Spine (Phila Pa 1976)*. 2013;38(15):1304–1309.

17. Schoenfeld AJ, Reamer EN, Wynkoop EI, Choi H, Bono CM. Does patient sex affect the rate of mortality and complications after spine surgery? A systematic review. *Clin Orthop Relat Res*. 2014;473(8):2479–2486.

18. Schoenfeld AJ, Tipirneni R, Nelson JH, Carpenter JE, Iwashyna TJ. The influence of race and ethnicity on complications and mortality after orthopedic surgery: a systematic review of the literature. *Med Care*. 2014;52(9):842–851.

19. Overview of National Inpatient Sample. http://www.hcup-us.ahrq.gov/nisoverview.jsp. Accessed August 21, 2016.

20. Introduction to the HCUP National Inpatient Sample (NIS) 2013. https://www.hcup-us.ahrq.gov/db/nation/nis/NIS_Introduction_2013.jsp. Accessed August 21, 2016.

21. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care*. 2005;43(11):1130–1139.

22. Deyo RA, Cherkin DC, Ciol MA. Adapting a clinical comorbidity index for use with *ICD-9-CM* administrative databases. *J Clin Epidemiol*. 1992;45(6):613–619.

23. Ikard RW. Methods and complications of anterior

exposure of the thoracic and lumbar spine. *Arch Surg*. 2006;141(10):1025–1034.

24. Fu R, Selph S, Mcdonagh M, Peterson K, Tiwari A, Chou R, Helfand M. Effectiveness and harms of recombinant human bone morphogenic protein-2 in spine fusion: a systematic review and meta-analysis. *Ann Intern Med*. 2013;158(13):890–902.

25. Simmonds MC, Brown JVE, Heirs M, et al. Safety and effectiveness of recombinant human bone morphogenic protein-2 for spinal fusion: a meta-analysis of individual-participant data. *Ann Intern Med*. 2013;158(12):877–889.

26. Baird EO, Egorova NN, McAnany SJ, et al. National trends in outpatient surgical treatment of degenerative cervical spine disease. *Glob Spine J*. 2014;4(3):143–150.

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Appendix A. ICD-9-CM codes used in this analysis to identify relevant spinal diagnoses.

Code	Region	Diagnosis
72210	Lumbar	Disc displacement
72402	Lumbar	Stenosis
7220	Cervical	Disc displacement
72252	Lumbar	Disc degeneration
7384	Nonspecific	Spondylolisthesis
7213	Lumbar	Spondylosis
7211	Cervical	Spondylotic myelopathy
7210	Cervical	Spondylosis
72271	Cervical	Disc displacement w myelopathy
7230	Cervical	Stenosis
7224	Cervical	Disc degeneration
75612	Nonspecific	Spondylolisthesis
99649	Nonspecific	Mechanical complication of internal ortho device
72273	Lumbar	Disc displacement with myelopathy
72403	Lumbar	Stenosis with claudication
72283	Lumbar	Postlaminectomy syndrome
73730	Nonspecific	Idiopathic scoli
8054	Lumbar	Closed fracture
99678	Nonspecific	Other complication ortho device
7224	Cervical	Disc degeneration
9964	Nonspecific	Carotid sinus
73313	Nonspecific	Pathologic fracture
72740	Nonspecific	Cyst
72293	Lumbar	Disc disorder unspecified
8052	Thoracic	Closed fracture
3484	Nonspecific	Compression of brain
7234	Nonspecific	Brachial neuritis
3241	Nonspecific	Intraspinal abscess
72142	Lumbar	Spondylolisthesis
99859	Nonspecific	Postop infection
73739	Nonspecific	Scoliosis
72211	Thoracic	Disc displacement
72272	Thoracic	Disc displacement w myelo
99709	Nonspecific	Nervous system complications
73382	Nonspecific	Fracture nonunion
72291	Cervical	Other unspecified disc disorder
80502	Cervical	Closed fracture
80506	Cervical	Closed fracture
73028	Nonspecific	Osteomyelitis
72401	Thoracic	Stenosis
8064	Lumbar	Closed fracture
73710	Nonspecific	Kyphosis
7246	Lumbar	Sacrum
99812	Nonspecific	Hematoma comp
83920	Lumbar	Dislocation of vertebra
80505	Cervical	Closed fracture
72141	Thoracic	Spondy w myelo
3492	Nonspecific	Meninges
80605	Cervical	Fracture
7242	Lumbar	Low back pain
7217	Nonspecific	Traumatic spondy
80507c	Cervical	Fracture
2254	Nonspecific	Meninges
2273	Nonspecific	Pituitary
3811	Nonspecific	Endarterectomy
99667	Nonspecific	Complication of ortho device
99701	Nonspecific	Nervous complication
430	Nonspecific	Hemorrhage
3315	Nonspecific	Idiopathic hydrocephalus
95203	Cervical	Central cord syndrome
73719	Nonspecific	Kyphosis
7218	Nonspecific	Spine nec
80625	Thoracic	Fracture
80609	Cervical	Fracture
72251	Thoracic	Degeneration of IVD
75611	Lumbar	Spondy
7981	Nonspecific	Death
83905	Cervical	Dislocation
9962	Nonspecific	Malfunction of neuro device
80501	Cervical	Fracture
80606	Cervical	Fracture
80626	Thoracic	Fracture
80508	Cervical	Fracture
99813	Nonspecific	Seroma
80600	Cervical	Cord injury
80504	Cervical	Fracture
2252	Nonspecific	Meninges
34460	Nonspecific	Neurogenic bladder
3360	Nonspecific	Syringomyelia
95208	Cervical	Central cord syndrome
80629	Thoracic	Fracture
3313	Nonspecific	Hydrocephalus
99640	Nonspecific	Complication of device
73712	Nonspecific	Kyphosis
99889	Nonspecific	Complication nec
20300	Nonspecific	Myeloma

Appendix A. Continued.

Code	Region	Diagnosis
7222	Cervical	Degeneration of IVD
83906	Cervical	Dislocation
34981	Nonspecific	Rhinorrhea
7200	Nonspecific	Ankylosing Spondy
83908	Cervical	Dislocation
3361	Nonspecific	Vascular myelopathy
7212	Thoracic	Spondylosis
83904	Cervical	Dislocation
72281	Cervical	Postlaminectomy
80608	Cervical	Central cord syndrome
71888	Nonspecific	Derangement nec
389	Nonspecific	Hearing loss
7231	Cervical	Neck pain
73018	Nonspecific	Osteomyelitis
74101	Nonspecific	Spina bifida
80604	Cervical	Cord injury
80503	Cervical	Fracture
75619	Nonspecific	Anomaly
7385	Nonspecific	Deformity
3812	Cervical	Head and neck vessels
4373	Nonspecific	Cerebral aneurysm
80621	Thoracic	Fracture
99851	Nonspecific	Infection
95200	Cervical	Spinal cord
3369	Nonspecific	Spinal cord
7202	Lumbar	Sacroiliitis
7243	Nonspecific	Sciatica
99675	Nonspecific	Complication
72292	Thoracic	Disc degen
7238	Cervical	Syndrome
72400	Nonspecific	Stenosis
80601	Cervical	Fracture
80603	Cervical	Fracture
80620	Thoracic	Fracture
72190	Nonspecific	Spondy wo myelo
95205	Cervical	Spinal cord
83903	Cervical	Dislocation
73734	Thoracic	Scoliosis
99663	Nonspecific	Graft comp
7245	Nonspecific	Back ache
72282	Thoracic	Postlaminectomy
3314	Nonspecific	Hydrocephalus
3482	Nonspecific	Tumor
99647	Nonspecific	Implant
7320	Nonspecific	Juvenile osteochondrosis
95204	Cervical	Spinal cord
4412	Thoracic	Aneurysm
73329	Nonspecific	Bone cyst
7248	Nonspecific	Other back
80624	Thoracic	Cord injury
42	Nonspecific	Esophagus
7292	Nonspecific	Neuralgia
73320	Nonspecific	Cyst of bone
7237	Cervical	Ossification cerv
4417	Thoracic	Aneurysm
99832	Nonspecific	Disruption
73390	Nonspecific	Bone and cartilage disorder nos
7226	Nonspecific	IVD degeneration
4320	Nonspecific	Hemorrhage
2148	Nonspecific	Lipoma
431	Nonspecific	Hemorrhage
3480	Nonspecific	Cerebral cyst
7542	Nonspecific	Congenital musculoskeletal deformity
8056	Lumbar	Fracture
99659	Nonspecific	Malfunction of device
3559	Nonspecific	Mononeuritis
7249	Nonspecific	Back disorder
33818	Nonspecific	Postop pain
99641	Nonspecific	Mechanical loosening of joint
99677	Nonspecific	Complication of joint
34931	Nonspecific	Puncture of dura

Abbreviations: *ICD-9, International Classification of Diseases, Ninth Revision, Clinical Modification*; IVD, intervertebral disc.

Appendix B.

Procedure-Related Complications	*ICD-9-CM* Codes
Organ-specific complications	
Dysphasia	478.30, 478.31, 478.32, 478.33, 478.34, 784.4, 787.2
Nervous system	997.0, 997.00, 997.01, 997.02, 997.09
Cardiac	997.1
Peripheral vascular	997.2
Respiratory	997.3, 997.30, 997.39
Digestive system	997.4
Urinary	997.5
Other complications of procedures	
Device-related	996.00, 996.4, 996.40, 996.41, 996.42, 996.43, 996.44, 996.45, 996.46, 996.47, 996.49
Post-op shock	998.0
Hematoma/seroma	998.1, 998.12, 998.13
Puncture vessel/nerve	998.2
Wound dehiscence	998.3, 998.30, 998.31, 998.32, 998.33
Postoperative infection	998.5, 998.51, 998.59
Acute posthemorrhagic anemia	285.1
Adult respiratory distress syndrome	518.5
Pulmonary embolism	415.1, 415.11, 451.19
Deep vein thrombosis	451.11, 451.19, 451.2, 451.81, 451.9, 453.40, 453.41, 453.42, 453.9
Venous thrombotic events	415.1, 415.11, 451.19, 451.11, 451.19, 451.2, 451.81, 451.9, 453.40, 453.41, 453.42, 453.9

Abbreviation: *ICD-9-CM*, *International Classification of Diseases, Ninth Revision, Clinical Modification*.