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SURGERY

Surgeon Specialty and Outcomes After Elective Spine Surgery

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Study Design. Retrospective cohort analysis of prospectively collected clinical data.

Objective. To compare outcomes of elective spine fusion and laminectomy when performed by neurological and orthopedic surgeons.

Summary of Background Data. The relationship between primary specialty training and outcome of spinal surgery is unknown.

Methods. We analyzed the 2006 to 2012 American College of Surgeons National Surgical Quality Improvement Project database of 50,361 patients, 33,235 (66%) of which were operated on by a neurosurgeon. We eliminated all differences in preoperative and intraoperative risk factors between surgical specialties by matching 17,126 patients who underwent orthopedic surgery (OS) to 17,126 patients who underwent neurosurgery (NS) on propensity scores. Regular and conditional logistic regressions were used to predict adverse postoperative outcomes in the full sample and matched sample, respectively. The effect of perioperative transfusion on outcomes was further assessed in the matched sample.

Results. Diagnosis and procedure were the only factors that were found to be significantly different between surgical subspecialties in the full sample. We found that compared with patients who underwent NS, patients who underwent OS were more than twice as likely to experience prolonged length of stay (LOS) (odds ratio: 2.6, 95% confidence interval: 2.4–2.8), and significantly more likely to receive a transfusion perioperatively, have complications, and to require discharge with continued care. After matching, patients who underwent OS continued to have slightly higher odds for prolonged LOS, and twice the odds for receiving perioperative transfusion compared with patients who underwent NS. Taking into account perioperative transfusion did not eliminate the difference in LOS between patients who underwent OS and those who underwent NS.

Conclusion. Patients operated on by OS have twice the odds for undergoing perioperative transfusion and slightly increased odds for prolonged LOS. Other differences between surgical specialties in 30-day postoperative outcomes were minimal. Analysis of a large, multi-institutional sample of prospectively collected clinical data suggests that surgeon specialty has limited influence on short-term outcomes after elective spine surgery.

Key words: spine, comparative effectiveness, neurosurgery, orthopedic surgery, outcomes, health services research, morbidity, mortality, length of hospitalization, complications.

Level of Evidence: 3

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Both neurological and orthopedic surgeons operate on the spine. However, there are dissimilarities in training for spine surgery between the 2 fields with respect to both the amount of exposure and scope of practice. It is unknown whether these differences in training or practice yield different outcomes. We used the National Surgical Quality Improvement Program (NSQIP), a prospectively collected, clinical database, with proven validity and reproducibility,[1] to conduct a comparative effectiveness study of early (≤30 d) perioperative complications after elective fusion and/or laminectomy when performed by neurosurgeons and orthopedic surgeons.

MATERIALS AND METHODS

Database

We used the American College of Surgeons' NSQIP to identify patients who underwent spine surgery between 2006 and

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2012. This database consists of prospectively collected, clinical data from nearly 400 community and academic hospitals in the United States. Data consist of 252 variables that include demographic variables, preoperative laboratory values, preexisting comorbidities, intraoperative variables, and 30-day postoperative morbidity and mortality. Sites that contribute data into NSQIP undergo annual inter-rater reliability audit to ensure accurate data collection, making NSQIP a high-quality and reliable database.[1–3]

Subjects and Surgical Specialty

We originally identified 68,291 patients who underwent spine surgery between 2006 and 2012 (Figure 1). We excluded emergency cases (n = 1539), patients with septic shock (n = 42), and those who received preoperative transfusion (n = 269), features that dictate a distinct postoperative course.[4] The focus of this study was on patients who underwent fusion, laminectomy, or both. Each patient in the NSQIP database has 1 primary *Current Procedure Terminology* (*CPT*) code, and up to 10 additional secondary *CPT* codes. Patients who had any 1 or more *CPT* code between 22531 and 22820 were considered to have undergone spine fusion. Patients who had any 1 or more *CPT* code between 63000 and 63052 were considered to have undergone laminectomy. We excluded patients who did not undergo spine fusion or laminectomy (n = 7896). We limited our sample to the most common diagnostic codes in patients undergoing laminectomy, fusion, or both. We included patients with the following *International Classification of Diseases, Ninth Revision* (*ICD-9*), codes: spondylosis (721.0–721.42, 721.9, and 721.91); disc displacement (722.0–722.2); disc degeneration (722.4–722.6); intervertebral disc disorder (722.7–722.73); spinal stenosis (723.0 and 724.0–724.09), and spondylolisthesis (738.4 and 756.12). Patients with other diagnoses were excluded (n = 8184). Our final study sample consists of 50,361 patients who underwent fusion and/or laminectomy. We stratified patients according to the primary surgical specialty of the attending surgeon leading the operating team, with 33,235 (66%) patients operated on by a neurosurgeon and 17,126 by an orthopedic surgeon.

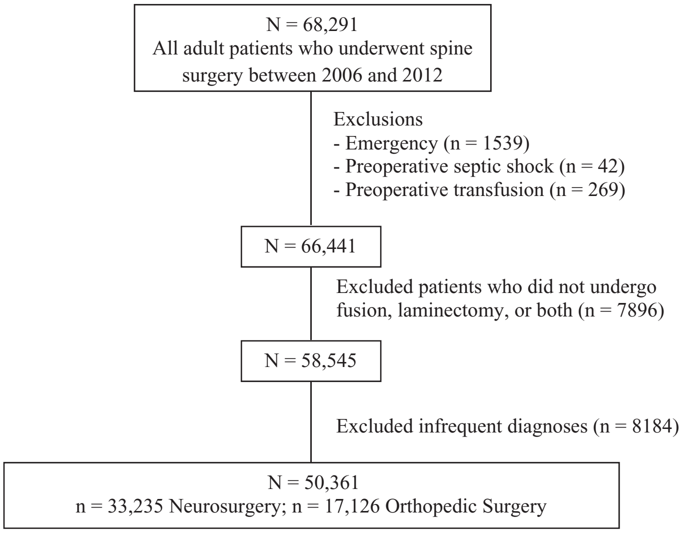

Figure 1. *Flow chart of patient selection*. We depict the inclusion and exclusion criteria used to obtain the study population. Details of the *ICD-9* diagnosis and *CPT* procedure codes for inclusion or exclusion are enumerated in the Materials and Methods section. *ICD-9* denotes *International Classification of Diseases, Ninth Revision*; *CPT*, *Current Procedure Terminology*.

Covariates

We analyzed all available pre- and intraoperative factors in NSQIP that might have an effect on postoperative outcomes (Table 1). Age, body mass index, and surgical time were included as continuous variables. We merged race categories into Caucasian *versus* all other. We dichotomized both transfer and functional status, respectively, as admitted from home *versus* transferred from any facility and as independent *versus* partially or totally dependent. Patients who presented with acute mental status changes and/or delirium at the time of surgery were considered to have altered mental status. We classified patients who had a history of transient ischemic attacks or cerebrovascular accident with or without residual neurological deficits as having cerebrovascular comorbidities. Patients who required ventilator-assisted respiration during the 48 hours prior to surgery, had congestive heart failure that was diagnosed or was symptomatic within 30 days prior to surgery, self-reported angina in the month leading up to surgery, myocardial infarction within the 6 months prior to surgery, any history of percutaneous coronary intervention, prior cardiac surgery, angioplasty, or revascularization procedure for atherosclerotic peripheral vascular disease, or if they were experiencing rest pain or gangrene were considered to have cardiopulmonary comorbidities. Preoperative hemostatic screening laboratory values were recorded in the NSQIP database if drawn within 90 days prior to the surgical procedure, and were considered abnormal according to commonly accepted guidelines.[5] Patients were defined as having renal comorbidities if they had renal disease, abnormal blood urea nitrogen, or creatinine laboratory values. We defined cancer comorbidities as presenting with disseminated cancer, unintentional weight loss more than 10% of body weight in the 6 months preceding surgery, or receiving chemotherapy or radiotherapy within 90 days prior to surgery. Self-reported patient history of abnormal bleeding, self-reported family history of bleeding disorders, vitamin K deficiency, and a comprehensive list of medications that pose a risk for bleeding abnormalities were captured through the NSQIP variable "bleeding disorders." Patients with bleeding disorders or abnormal preoperative international normalized ratio or platelet count were considered to have bleeding risk factors. Anemia was defined as hematocrit less than 36% in females or less than 41% in males. Abnormal liver function tests were defined as abnormal bilirubin, alkaline phosphatase, aspartate transaminase, or albumin. We looked at the presence of resident physicians in the operating room as a surrogate marker for academic institutions. We created a new variable, "multiple *CPT* codes," to capture patients who underwent more than

TABLE 1. Baseline Characteristics in the General and Matched Cohort,* Stratified by Surgical Specialty

	General Cohort (N = 50,361)			Matched Cohort (N = 34,252)		
	Neurosurgery (n = 33,235; 66.0%)	Orthopedic Surgery (n = 17,126; 34.1%)	Absolute Standardized Difference†	Neurosurgery (n = 17,126; 50%)	Orthopedic Surgery (n = 17,126; 50%)	Absolute Standardized Difference†
Age, years, mean ± SD	57 ± 14	57 ± 15	0.01	57 ± 14	57 ± 15	0.03
Female	47.5%	49.7%	0.04	49.8%	49.7%	0.00
Caucasian	81.5%	81.9%	0.01	82.1%	81.9%	0.01
Admitted from home	98.7%	99.3%	0.06	98.9%	99.3%	0.05
Smoking status						
Never	67.1%	70.6%	0.07	67.2%	70.6%	0.07
Current	25.4%	22.5%		25.4%	22.5%	
Previous	7.5%	6.9%		7.4%	6.9%	
>2 alcoholic drinks per day	3.6%	2.8%	0.04	3.6%	2.8%	0.04
Partially or fully dependent functional status	3.5%	2.4%	0.06	3.2%	2.4%	0.05
ASA						
1 and 2	58.9%	62.4%	0.07	57.7%	62.4%	0.10
3 and 4	41.1%	37.6%		42.3%	37.6%	
BMI, kg/m^2, mean ± SD	30.1 ± 27.2	30.1 ± 6.6	0.00	30.0 ± 6.3	30.1 ± 6.6	0.02
Diabetes mellitus	15.4%	14.7%	0.02	15.5%	14.7%	0.02
Cerebrovascular comorbidities	3.2%	3.3%	0.01	3.4%	3.3%	0.01
Cardiopulmonary comorbidities	12.8%	11.9%	0.03	13.0%	11.9%	0.03
Hypertension requiring medication	49.1%	49.8%	0.01	50.6%	49.8%	0.02
Renal comorbidities	22.0%	21.9%	0.00	22.5%	21.9%	0.02
Cancer comorbidities	0.9%	1.1%	0.01	0.9%	1.1%	0.02
Steroid use for chronic condition	3.5%	2.9%	0.03	3.4%	2.9%	0.03
Sepsis or SIRS	0.6%	0.5%	0.01	0.5%	0.5%	0.01
Prior operation within 30 d	0.6%	1.0%	0.05	0.5%	1.0%	0.05
Bleeding risk factors	5.8%	6.0%	0.01	5.8%	6.0%	0.01
Anemia	20.8%	20.2%	0.02	21.0%	20.2%	0.02
Abnormal LFT	5.2%	6.0%	0.04	5.0%	6.0%	0.04
Abnormal Na	5.9%	5.2%	0.03	6.1%	5.2%	0.04
Abnormal WBC count	13.1%	12.5%	0.02	12.8%	12.5%	0.01
Resident in the OR	32.4%	28.9%	0.08	32.7%	28.9%	0.08
Length of surgery, min, mean ± SD	143 ± 90	148 ± 96	0.06	155 ± 96	148 ± 96	0.08
Type of procedure undergone						
Fusion	32.2%	36.4%	**0.21**	34.5%	36.3%	0.05
Laminectomy	53.6%	43.6%		43.9%	43.6%	
Fusion and laminectomy	14.2%	20.0%		21.6%	20.0%	

(Continued)

TABLE 1. (*Continued*)

	General Cohort (N = 50,361)			Matched Cohort (N = 34,252)		
	Neurosurgery (n = 33,235; 66.0%)	**Orthopedic Surgery (n = 17,126; 34.1%)**	**Absolute Standardized Difference†**	**Neurosurgery (n = 17,126; 50%)**	**Orthopedic Surgery (n = 17,126; 50%)**	**Absolute Standardized Difference†**
Diagnosis						
Spondylosis	18.7%	10.3%	**0.39**	10.3%	10.3%	0.06
Disk displacement	38.0%	32.7%		32.7%	32.7%	
Disk degeneration	6.9%	15.3%		13.4%	15.3%	
Intervertebral disk disorder	4.9%	3.3%		3.3%	3.3%	
Spine stenosis	25.3%	29.0%		30.0%	29.0%	
Acquired congenital spondylolisthesis	6.2%	9.5%		10.5%	9.5%	
Multiple CPT codes	57.6%	63.3%	0.12	63.4%	63.3%	0.00
Multilevel surgery	28.4%	35.9%	0.16	30.7%	35.9%	0.11

**Propensity score consists of diagnostic and procedure codes, defined according to CPT and ICD-9 codes.*

†Significant standardized differences (>0.20) are bolded.

ASA indicates American Association of Anesthesiologists; BMI, body mass index; COPD, chronic obstructive pulmonary disease; CPT, Current Procedural Terminology; ICD-9, International Classification of Diseases, Ninth Revision; Na, sodium; OR, operating room; SD, standard deviation; SIRS, systemic inflammatory response syndrome; LFT, liver function test; WBC, white blood cell.

1 procedure, thus having more than 1 *CPT* code. We also used *CPT* codes to identify all patients who underwent multilevel surgery. Patients with the following *CPT* codes were considered to have multilevel surgery: 63015, 63016, 63017, 63035, 63044, 63048, 63050, 63051, 22585, 22614, 22632, 22800, 22802, 22804, 22808, 22810, 22812, and/or 22819.

Outcomes

Outcomes of interest (Table 2) were: (1) total length of stay (LOS), assessed as a continuous variable; (2) prolonged LOS, which we arbitrarily chose to define as postoperative hospitalization longer than the third quartile of the entire study population, or here, more than 4 days; (3) Perioperative transfusion, defined as transfusion of 1 unit or more of whole blood or packed red blood cells any time from the start of surgery to 72 hours after surgery; (4) minor postoperative complications defined as one or more of: superficial surgical site infection, urinary tract infection, deep venous thrombosis, or thrombophlebitis; (5) major postoperative complications defined as deep incision surgical site infection, organ or space surgical site infection, wound disruption, pneumonia, unplanned intubation, pulmonary embolism, more than 48-hour postoperative ventilator-assisted respiration, progressive renal insufficiency, acute renal failure, cardiovascular accident with neurological deficit, coma of more than 24 hours, peripheral nerve injury, cardiac arrest requiring CPR, myocardial infarction, graft, prosthesis or flap failure, sepsis, septic shock, and/or 30-day return to the operating room; (6) any postoperative complication, defined as having at least 1 minor or major complications or unplanned return to the operating room; (7) discharged with continued care, defined as patients who were discharged to home with continued care or to a facility with skilled or unskilled care but who had not initially been admitted from such a facility; (8) 30-day readmission, defined as unplanned readmission to any hospital within 30 days of discharge; (9) unplanned return to the operating room, defined as any unplanned return to the operating room within 30 days of surgery; (10) 30-day readmission, defined as readmission to hospital within 30 days of index surgery after initial discharge; and (11) 30-day mortality, which constitutes death within 30 days after index surgery regardless of hospitalization status. Data on discharge destination and readmission are only available in NSQIP for the years 2011 and 2012.

Statistical Analyses

We compared pre- and intraoperative factors according to surgeon specialty using standardized differences (Table 1). This statistical measure is the ideal tool to assess intragroup differences in covariate balance because, unlike significance tests such as the Pearson χ^2 test or Fisher exact test, which generate *P* values, standardized differences are not affected by sample size.[6] This is important in matched analyses, where the invariably smaller sample size of the matched cohort may result in statistically insignificant *P* values that is falsely interpreted as improved covariate balance. An absolute standardized difference of more than 0.20 was considered statistically significant.[7] We found that only diagnosis and procedure were significantly different between patients who underwent neurosurgery (NS) and those who underwent orthopedic surgery (OS) (Table 1). Given the nonrandomized design of this study,

TABLE 2. Thirty-Day Perioperative Complications in the General and Matched Cohort,* Stratified by Surgical Specialty

Outcomes	General Cohort (N = 50,361)		Matched Cohort (N = 34,252)	
	Neurosurgery (n = 33,235; 66.0%)	Orthopedic Surgery (n = 17,126; 34.1%)	Neurosurgery (n = 17,126; 50%)	Orthopedic Surgery (n = 17,126; 50%)
Total length of hospital stay, mean ± SD, d	3 ± 9	3 ± 5	3 ± 8	3 ± 5
Median	2	3	2	3
Prolonged LOS (>4 d)	21.4	28.7	24.8	28.7
Perioperative transfusion	4.6	11.1	6.2	11.1
Minor postoperative complications	2.5	2.9	2.6	2.9
Superficial surgical site infection	0.9	0.9	0.9	0.9
Urinary tract infection	1.2	1.5	1.3	1.5
DVT or thrombophlebitis	0.5	0.5	0.5	0.5
Major postoperative complications	4.1	4.8	4.4	4.8
Deep incision surgical site infection	0.5	0.6	0.5	0.6
Organ or space surgical site infection	0.2	0.1	0.2	0.1
Wound disruption	0.2	0.2	0.2	0.2
Pneumonia	0.5	0.5	0.5	0.5
Unplanned intubation	0.4	0.4	0.3	0.4
>48 hr postoperative ventilator-assisted respiration	0.3	0.3	0.2	0.3
Pulmonary embolism	0.3	0.4	0.3	0.4
Renal insufficiency or failure	0.1	0.2	0.1	0.2
Cerebrovascular accident with neurological deficit	0.1	0.1	0.1	0.1
Coma of >24 hr	0.0	0.0	0.0	0.0
Peripheral nerve injury	0.1	0.2	0.1	0.2
Cardiac arrest or MI	0.3	0.4	0.3	0.4
Graft, prosthesis or flap failure	0.0	0.0	0.0	0.0
Sepsis or septic shock	0.6	0.7	0.7	0.7
Any postoperative complication†	5.9	6.8	6.3	6.8
Discharged with continued care‡	10.0	11.8	11.1	11.8
30-day readmission‡	4.5	4.4	4.5	4.4
30-day return to the OR	2.5	2.8	2.6	2.8
30-day mortality	0.1	0.2	0.1	0.2

**Propensity score consists of diagnostic and procedure codes, defined according to CPT and ICD-9 codes.*

†≥1 minor or major complications.

‡Data only available for 2011 and 2012.

DVT indicates deep venous thrombosis; ICD-9, International Classification of Diseases, Ninth Revision; LOS, Length of Stay; MI, myocardial infarction; OR, operating room; SD, standard deviation.

our best option to control for imbalance with regard to these covariates was to generate a propensity score that included both diagnosis and procedure variables.[6,8] We used the 1:1 greedy matching technique[8–10] to match patients who underwent OS with those who underwent NS according to their respective propensity score. In greedy matching, a patient who underwent OS is selected at random and matched to a patient who underwent NS whose propensity score is closest to that of the patient who underwent OS.[10] This process was then repeated until all patients who underwent OS are matched to those who underwent NS. We successfully matched 17,126 patients who underwent OS to 17,126 those who underwent NS, to create our matched cohort. To ensure covariate balance was achieved with propensity score matching, we compared baseline characteristics of patients in the matched cohort using standardized difference We no longer find any covariate imbalance (Table 1).

We used logistic regression analysis to determine whether surgical specialty was independently associated with adverse outcomes in the unmatched cohort (Table 1). Because of the matched nature of the data, we used conditional logistic regression analysis to model the relationship between surgical subspecialty and adverse outcomes in the matched cohort.[7,11] To assess whether differences in outcomes in our matched sample are the result of surgical specialty alone or use of perioperative transfusion, we used multivariate logistic regression including surgical specialty and perioperative transfusion to predict each adverse outcome of interest (Table 3). SAS (version 9.2; SAS Institute, Cary, NC) was used.

RESULTS

Pre- and intraoperative characteristics according to surgical specialty are listed in Table 1. The diagnosis and procedure were not balanced between patients who underwent NS and those who underwent OS (with absolute standardized difference of 0.39 and 0.21, respectively). In our sample of 50,361 patients, patients who underwent OS underwent fusion and laminectomy more commonly compared with those who underwent NS (20.0% *vs.* 14.2%, standardized differences of 0.21). Neurosurgeons are operating on more patients with spondylosis and disk displacement, whereas orthopedic surgeons more frequently operated on patient with disk degeneration (standardized differences of 0.39).

Frequency of outcomes was compared between patients who underwent NS and those who underwent OS (Table 2). Median length of hospitalization in patients who underwent OS was 3.0 days *versus* 2.0 days in patients who underwent NS. LOS according to surgical specialty in the general cohort and in the matched cohort is graphically shown in Supplemental Digital Content, Figures 1 and 2, respectively (available at http://links.lww.com/BRS/A883 and http://links.lww.com/BRS/A884). Prolonged length of hospitalization, complications, and discharge with continued care were slightly more prevalent in the patients who underwent OS. However, the incidence of 30-day readmission and 30-day mortality were almost identical between the specialties.

We matched 17,126 patients who underwent NS to 17,126 who underwent OS on propensity scores (Table 1). Once matched accurately and precisely in this manner, there is no covariate imbalance with regard to pre- and intraoperative factors, preoperative diagnoses leading to surgery, or operative procedures to treat those conditions between surgical specialties in the matched sample (Table 1). The frequencies of outcomes in the matched sample are found in Table 2.

Using logistic regression in the general cohort of 50,361 (Table 3), we found that patients who underwent OS were more than twice as likely to experience prolonged LOS, 1.4 times the odds for receiving perioperative transfusion, and

TABLE 3. Association Between Surgical Specialty and Perioperative Complications of Elective Spine Surgery in the General and Matched Cohorts

Outcomes	Logistic Regression in the Full Study Sample*	Conditional Logistic Regression in the Propensity Score-Matched Sample†	Conditional Multivariate Logistic Regression, Including Intra- and Postoperative Transfusion, in the Propensity Score-Matched Sample†
Prolonged LOS	**2.6 (2.4–2.8)**	**1.2 (1.2–1.3)**	**1.1 (1.1–1.2)**
Perioperative transfusion	**1.4 (1.4–1.5)**	**2.0 (1.8–2.1)**	NA
Minor complications	1.2 (1.0–1.3)	1.1 (1.0–1.2)	1.0 (0.9–1.1)
Major complications	**1.2 (1.1–1.3)**	1.1 (1.0–1.2)	1.0 (0.9–1.1)
Any complications	**1.2 (1.1–1.3)**	1.1 (1.0–1.2)	1.0 (0.9–1.1)
Discharged with continued care‡	**1.2 (1.1–1.3)**	1.1 (1.0–1.3)	1.0 (0.9–1.1)
30-day readmission‡	1.0 (0.9–1.1)	0.9 (0.8–1.1)	0.9 (0.7–1.0)
30-day return to OR	1.2 (1.0–1.3)	1.1 (0.9–1.2)	1.0 (0.9–1.2)
30-day mortality	1.7 (1.0–2.7)	1.8 (1.0–3.1)	1.9 (1.0–3.6)

Odd ratios that are significant are bolded.

**Logistic regression in total sample described in Tables 1 and 2 (N [neurosurgery] = 33,235; N [orthopedic surgery] = 17,126).*

†Conditional logistic regression in the propensity-score matched sample described in Table 1 (N [neurosurgery] = 17,126; N [orthopedic surgery] = 17,126). Propensity score was determined on the basis of diagnostic and procedure codes, defined according to CPT and ICD-9 codes.

‡Data only available for 2011 and 2012.

CPT indicates Current Procedural Terminology; ICD, International Classification of Diseases, Ninth Revision; LOS, length of hospital stay; NA, not applicable; OR, operating room.

significantly higher odds for complications and requiring discharge with continued care compared with patients who underwent NS.

In the matched cohort, we used conditional logistic regression to assess the relationship between surgical specialty and each outcome of interest (Table 3). We found that patients who underwent OS had only slightly higher odds for prolonged LOS than those who underwent NS. This finding is supported by the data on LOS (Table 2). In both the full and the matched samples, the median LOS for patients who underwent OS is 3 days, whereas that of those who underwent NS is 2 days. Increased likelihood for use of perioperative transfusion persisted in the matched sample, with patients who underwent OS having twice the odds for perioperative transfusion compared with those who underwent NS.

To assess whether increased use of perioperative transfusion by OS is the reason for slightly increased odds for prolonged LOS compared with patients who underwent NS, we used conditional multivariate logistic regression, including both perioperative transfusion and surgical specialty, as the predictor variables (Table 3). The odds for prolonged LOS continued to be slightly, but significantly higher, for patients who underwent OS after taking perioperative transfusion status into account (odds ratio: 1.1; 95% confidence interval: 1.1–1.2), which suggests that perioperative transfusion cannot fully account for longer hospital stay in patients who underwent OS.

DISCUSSION

We used a large, prospectively collected, clinical database, reported from hospitals nationwide, to conduct a comparative effectiveness analysis of patients undergoing spine surgery. In this analysis of more than 50,000 patients, the odds for prolonged LOS, perioperative transfusion, complications, and discharge with continued care were increased in the OS group. There were no significant differences in the pre- or intraoperative characteristics of NS *versus* OS groups after matching for preoperative diagnosis and surgical procedure performed. Patients who underwent OS continued to have slightly higher odds for prolonged LOS in the matched sample, and twice the odds for perioperative transfusion.

Interpretations of Results

Increased odds for prolonged LOS in the absence of a specific correlation with postoperative complications raises the question why patients who underwent OS stay in the hospital longer. As shown in Table 2, a prolonged LOS was the most frequent outcome identified, with 21.4% of NS and 28.7% of patients who underwent OS experiencing protracted stay postoperatively. Because after adjusting and carefully matching the 2 cohorts, the increased odds for prolonged LOS in patients who underwent OS persisted (Table 3), we are confident that our analysis for this specific outcome possessed sufficient power to detect differences between the 2 patient groups. It is important to note that not all analyses in this report are equally powered. The American College of Surgeons started collecting data on discharge with continued care, and readmission within 30 days of the index surgery, in 2011. Similarly, it is gratifying to observe that less than 1% of the patients in both groups died within 30 days of surgery, resulting in a relatively low number of subjects available for this outcome measure. Thus, analyses of 30-day readmission and 30-day mortality rates may be prone to type II error, the probability that there was in fact an association between a surgical specialty, either NS or OS, and either early readmission or mortality when compared with its counterpart, but was missed. Nevertheless, this study includes tens of thousands of patients for whom numerous, relevant perioperative variables and multiple, important outcomes were analyzed.

Interpretations in the Context of the Literature

Classification of the operating team, as NS or OS, is based on the primary specialty of the attending surgeon and does not take into account fellowship training or time practicing as a surgeon, which may influence outcomes.[12] It is not possible to assess whether surgical outcomes differ between fellowship-trained spine neurosurgeons, general neurosurgeons, and orthopedic spine surgeons in this study because we do not have these data available in NSQIP.

NSQIP does not contain any institutional related data, including data on clustering to show patients operated on by the same surgeon or coming from the same institution. We used presence of resident in the operating room as a surrogate for academic institutions. There is controversy in the literature as to the effect that surgeon and hospital volume may have on outcomes. Although hospital volume has been shown to affect OS outcomes, studies have focused on knee and hip replacements; there have been few studies including patients who underwent spine surgery.[13] A study looking at the effect of hospital and surgeon volume on postoperative complications after lumbar spine surgery used the Nationwide Inpatient Sample to identify 232,668 hospitalization records of patients who underwent lumbar spine surgery between 1992 and 2005.[14] The authors concluded that patients who were treated both by high-volume surgeons and in high-volume hospitals had lower odds for postoperative compilations and mortality.[14] Another study using the Nationwide Inpatient Sample, between 2005 and 2008, found that patients treated by very-low volume surgeons, defined by less than 15 procedures in 4 years, experienced higher rate of complications.[15] However, after adjusting for surgeon volume, hospital size was not a predictor of poor outcomes.[15] There is also controversy about the appropriate methodological approach to assess the relationship between volume and outcomes,[16] which adds to controversy of the association between spine surgery outcomes relative to both hospital and surgeon volume. We were not able to assess the effect of hospital and surgeon volume on outcomes in our study because this data are not available in NSQIP.

Clinical Implications

In this analysis of more than 50,000 patients in whom elective spine surgery was performed, by both orthopedic and neurological surgeons, we found only small differences in outcome, principally related to prolonged LOS, perioperative transfusion, major postoperative complications or any complication, and discharge with continued care. Once the patients were carefully matched on the basis of preoperative diagnosis that led to surgery and the procedure that was performed, there remained a large collection of 34,252 patients (17,126 in each matched group). Further analysis (Table 3) showed persistent, small increases in the OS group, compared with the NS group, only in prolonged LOS (odds ratio, 1.1; range, 1.1–1.2) and in intra- or postoperative transfusion (odds ratio, 2.0; range, 1.8–2.1). These findings, across a large range of demographic features, preoperative variables and comorbidities, and intraoperative factors, balanced, as well, by the matching by diagnosis code and procedure performed, suggest that there are few differences in outcome for patients who undergo elective spine surgery, when performed by a neurosurgeon or an orthopedic surgeon. These differences may become less over time as more multidisciplinary spine centers, which take advantage of the shared expertise of NS and OS and other care givers, develop and mature.[17] Furthermore, focusing attention on optimizing outcomes in spine surgery, as with other areas of medicine, will become even more paramount in the years ahead because the value of a medical or surgical therapy is defined more consistently, at least in part, by outcome and the resources that were required to achieve that outcome.[18]

Limitations

This study has limitations. Although NSQIP collects clinical data prospectively from nearly 400 institutions across the United States, this is a retrospective analysis because it is not possible to confirm definitively a cause-and-effect relationship between surgical specialty of the primary surgeon and the outcomes measured. Despite matching on propensity scores, this is not a randomized study, which means that we cannot rule out that the possibility that patients who underwent NS are different from those who underwent OS with regard to preoperative factors for which we are unaware. We investigated 30-day postoperative outcomes only; extrapolation beyond this time frame should be exercised with caution. Furthermore, we were unable to determine surgeons' precise training in spine surgery or overall practice experience, which may influence outcomes.[19–21] Although *CPT* codes quantified the general nature of the procedures performed, we recognize that they are an imperfect way to capture the exact nature of what occurs in the operating room. However, using both *CPT* surgical procedure codes and *International Classification of Diseases, Ninth Revision* diagnosis codes to stratify and then to match equivalent patients by the specialty of the operating surgeon, we have been able to identify accurately and faithfully any potential adverse outcomes in either group (Table 3). The patients underwent elective surgery and all emergencies were excluded, so our findings cannot be extended to this latter group. However, elective patients were studied because there is the opportunity to control or minimize preoperative conditions that may influence outcome, thus increasing the likelihood that adequate and fair comparisons can be drawn between the 2 surgical groups. The NSQIP database is prospectively collected from nearly 400 academic and nonacademic hospitals across the United States. Data collection is conducted in a standardized fashion, accurately and precisely, with yearly quality checks and data reporting that achieves more than 95% for 30-day outcomes in patients who underwent NS and those who underwent OS after spine surgery across a wide spectrum of perioperative variables and postoperative outcomes.

CONCLUSION

We compared early (≤30 d) perioperative outcomes in patients undergoing elective fusion and laminectomy spine surgery for common diagnoses between patients who underwent NS and those who underwent OS. In the unmatched cohort, patients who underwent OS had higher odds for prolonged LOS, perioperative transfusion, complications, and discharged with continued care. However, upon propensity score matching of patients according to diagnosis and procedure, patients who underwent OS continued to have slightly higher odds for prolonged LOS and twice the odds for perioperative transfusion. Controlling for perioperative transfusion did not eliminate the slight but significant association between OS and prolonged LOS. Using a large, multi-institutional sample of prospectively collected data, our analysis suggests that surgeon specialty is associated with perioperative transfusion and prolonged hospitalization, but has limited predictive value for other short-term outcomes, 30-day or less outcomes after elective spine fusion and/or laminectomy.

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➢ Key Points

- ☐ Orthopedic and neurological surgeons both perform spine surgery.
- ☐ We conducted a comparative effectiveness analysis that compared early (≤30 d) perioperative outcomes in patients operated on by either a neurological or an orthopedic surgeon.
- ☐ After adequate adjustment for comorbidities and by both diagnosis and procedure, it was found that patients undergoing spine surgery by an orthopedic surgeon were more likely to have protracted postoperative hospitalization and to receive perioperative transfusion, compared with those undergoing surgery by a neurosurgeon. All other outcomes were similar.

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