Comparative effectiveness of anesthetic technique on outcomes after lumbar spine surgery: a retrospective propensity score-matched analysis of the National Surgical Quality Improvement Program, 2009–2019

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ABSTRACT

Background The impact of anesthetic technique on spine surgery outcomes is controversial. Using a large national sample of patients, we compared outcomes after lumbar decompression under regional anesthesia (RA: spinal or epidural) or general anesthesia (GA).

Methods A retrospective population-based study of American College of Surgeons National Surgical Quality Improvement Program data (2009–2019). Patients were propensity score (PS) matched 3:1 (GA:RA) on demographic and surgical variables. The primary outcome was the association between anesthetic type and any complication (cardiac, pulmonary, renal, transfusion, stroke, infectious, deep vein thrombosis/pulmonary embolus). Secondary outcomes included the association between anesthetic type and individual complications, readmission and length of stay (LOS). Unadjusted comparisons (OR, 95% CI), logistic regression and adjusted generalized linear modeling (parameter estimate, PE, 95% CI) were performed before and after PS matching.

Results Of 1 51 010 cases, 149 996 (99.3%) were performed under GA, and 1014 (0.67%) under RA. After matching, 3042 patients with GA were compared with 1014 patients with RA. On unadjusted analyses, RA was associated with lower odds of complications (OR 0.43, 0.3 to 0.6, p<0.001), shorter LOS (RA: 1.1±3.8 days vs GA: 1.3±3.0 days; p<0.001) and fewer blood transfusions (RA: 3/1014, 0.3% vs GA: 40/3042, 1.3%; p=0.004). In adjusted analyses, RA was associated with fewer complications (PE −0.43, −0.81 to −0.06, p=0.02) and shorter LOS (PE −0.76, −0.90 to −0.63, p<0.001). There was no significant association between anesthetic type and readmission (PE −0.34, −0.74 to 0.05, p=0.09).

Conclusions Compared with GA, RA was associated with fewer complications, less blood transfusion and shorter LOS after spine surgery. Although statistically significant, the magnitude of effects was small and requires further prospective study.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Compared with general anesthesia, regional anesthesia improves outcomes after orthopedic surgery. It is unclear whether these benefits are present among patients undergoing spine surgery.

WHAT THIS STUDY ADDS

⇒ Regional anesthesia was associated with fewer complications after lumbar spine surgery. There was a lower incidence of blood transfusion and shorter length of stay among patients who received regional anesthesia, but no other differences in individual outcomes or complications between the two techniques.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These results suggest that regional anesthesia may be a modifiable factor to improve outcomes after lumbar spine surgery. However, given the rare use of regional anesthesia for spine surgery, more prospective research into technique-specific risks and benefits should be undertaken prior to widespread recommendations for use.

INTRODUCTION

A long history and large volume of research supports regional anesthesia (RA) as equivalent or superior to general anesthesia (GA) to improve outcomes after orthopedic surgery.[1] In contrast, the effect of anesthetic technique on outcomes after spine surgery is relatively understudied,[2] with conflicting evidence to conclude the superiority of one technique over the other for individual outcomes, including bleeding and transfusion, hemodynamic stability and early postoperative pain scores.[3–6] Three systematic reviews with meta-analysis on the topic urge caution in interpretation of the potential benefits of RA for spine surgery given the small number of prospective comparative studies with small sample sizes, significant risk of bias and high heterogeneity of included trials.[7–9] Population-based research overcomes several of these methodologic limitations, but similar to the clinical studies, comparative research into GA versus RA in spine surgery cohorts is not yet established.[10 11]

In the current study, we used population-based data derived from the American College of Surgeons National Surgical Quality Improvement Program

(ACS-NSQIP) data sets to compare the association of anesthetic type and outcomes after lumbar spine surgery, between 2009 and 2019. The primary outcome of interest was the association between anesthetic type and any complication within 30 days of surgery. We hypothesized that patients undergoing elective lumbar spine surgery under RA would comprise a minority of patients but that outcomes would be at least equivalent to patients who received GA.

METHODS

The study was performed in accordance with the ethical standards of the Declaration of Helsinki (1964) and its subsequent amendments, under exempt status granted by the Institutional Review Board at Hospital for Special Surgery. The study is reported following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[12]

Study population

Clinical information was extracted for patients who underwent lumbar spine surgery between 2009 and 2019 from the ACS-NSQIP data sets.[13] ACS-NSQIP Participant Use Data Files were queried using current procedural terminology (CPT) codes for lumbar decompression, laminectomy, laminotomy, foraminotomy and combined procedures (22102, 62380, 63005, 63011, 63012, 63017, 63030, 63047, 63056, 63035, 63048, 63 057 and 0275T) (online supplemental table 1). All patients who received GA or RA (spinal anesthesia; epidural anesthesia) were included. Exclusion criteria were surgery for trauma, fracture, neoplasm, infectious disease; patients ≤age 18; and other types of anesthesia (not recorded; combined spinal-epidural; monitored anesthesia care).

Baseline characteristics collected included: age, sex, race, body mass index (BMI), smoking status, American Society of Anesthesiologists (ASA) physical status classification, functional status (dependent, independent), comorbidities (diabetes mellitus, chronic obstructive pulmonary disease, heart failure, hypertension, dialysis, cancer and bleeding disorders) and surgical duration.

Outcomes

The primary outcome was complications within 30 days of surgery. Complications were defined in the NSQIP Participant Use Data Files[13] and included: myocardial infarction, cardiac arrest, pneumonia, unplanned intubation, failure to wean from ventilator, pulmonary embolus, deep vein thrombosis, progressive renal insufficiency, acute renal failure, stroke, blood transfusion, wound dehiscence, urinary tract infection, infection (superficial wound, deep wound or organ space), sepsis, septic shock. Secondary outcomes included the differences between anesthetic type and (1) individual complications, (2) discharge destination (home or non-home), (3) length of stay (LOS), (4) readmission, (5) reoperation and (6) 30-day mortality.

Statistical analysis

Propensity score matching and covariate adjustment

Due to the observational (non-randomized) nature of the data set, we used propensity score (PS) matching to minimize the effects of confounding factors when assessing differences in patient demographics and outcomes between procedures performed with GA and RA. Three-to-one greedy nearest-neighbor PS matching was performed using anesthesia type as the treatment indicator to match patients with GA to patients with RA. The probability of undergoing a lumbar spinal procedure with GA was calculated based on clinically relevant covariates, including age, sex, BMI, ASA classification and procedure. Matching was considered sufficient if the standardized mean difference (SMD) in the means of PSs were less than 0.1.[14]

The SMD was calculated for comparisons of variables between anesthetic type for both the unmatched and matched cohorts. To assess postoperative factors, Fisher's exact test was used for dichotomous and categorical variables; the Mann-Whitney (Wilcoxon rank-sum) test was used for continuous variables. For the matched cohort, unadjusted and adjusted logistic regression was used to assess the occurrence of any complication, readmission and length of hospital stay between the anesthetic types. Conditional logistic regression was performed with anesthesia group as the independent variable and 'readmission' and 'complication' as separate discrete outcome variables. Generalized linear models were used to measure the association between anesthesia type and 'length of stay' (LOS), 'readmission' and 'complication', with anesthesia group as a covariate and PS as a confounding factor. A log transformation was used to normalize LOS. For LOS=0, the small value of 0.01 was added in order to compute the natural log.

All statistical analyses were conducted using SAS software V.9.4 (SAS Institute, Cary, North Carolina) and significance was set at $p<0.05$ for all tests.

RESULTS

We identified 153 224 patients who underwent the included surgeries between 2009 and 2019. After excluding cases for ineligible CPT code (n=2083) or primary anesthetic type (n=131), 151 010 cases were available for analysis. Of these, 149 996 (99.3%) were performed under GA, and 1014 (0.67%) were performed under RA. There were 171 patients included in the GA group who also received spinal or epidural anesthesia (0.1%).

Table 1 shows the patient-related and surgical-related demographic variables by anesthesia type, before and after matching. For the unmatched cohort, significant differences were found in the SMD for age, race, BMI, baseline comorbidities, duration of surgery and number of lumbar levels operated.

After PS matching, 3042 (75%) patients with GA were compared with 1014 (25%) patients with RA (table 1). None of the variables used to PS match (age, sex, BMI, outpatient procedure and ASA class) was statistically significantly different after matching. Demographic and perioperative variables were well balanced, with the exception of mean operative time (18 min longer for GA, SMD 0.317) and race (fivefold fewer African American patients received RA; SMD 0.109).

Postoperative complications and discharge variables for the matched and unmatched cohorts are presented in table 2. The incidence of any complication was significantly higher among patients who received GA (n=8602/149,996, 5.7%) compared with RA (n=25/1014, 2.5%; $p<0.001$) on unmatched comparisons, but not after PS matching (GA:110/3042, 3.6%; RA: 25/1014, 2.5%; p=0.085). On unmatched comparisons, the incidence of deep vein thrombosis (0.4% vs 0; p=0.017), reoperation (2.5% vs 1.4%, $p<0.03$) and readmission (4% vs 2.5%, p=0.002) was all statistically higher in the GA versus RA cohorts, respectively, but not after PS matching.

The incidence of blood transfusion was significantly higher in the GA cohort, compared with RA in both the unmatched (3286/149,996, 2.2% vs 3/1014, 0.3%; $p<0.0001$) and PS-matched comparisons (40/3042, 1.3% vs 3/1014, 0.3%; p=0.004). Length of hospital stay was significantly longer among patients who received GA in both the unmatched (1.9±3.4 days

Table 1 Patient demographics, preoperative and operative variables

Variable	Unmatched			Matched		
	General anesthesia (n=1 49 996)	Regional anesthesia (n=1014)	SMD*	General anesthesia (n=3042)	Regional anesthesia (n=1014)	SMD*
Demographics						
Age, mean (SD)	57.54 (15.8)	53.45 (16.2)	**0.257**	53.45 (16.1)	53.45 (16.2)	0.000
Female sex, n (%)	65 506 (43.7)	433 (42.7)	0.020	1307 (43.0)	433 (42.7)	0.005
Race, n (%)						
White	118 867 (79.2)	844 (83.2)	**0.102**	2478 (81.5)	844 (83.2)	0.047
African American	10 441 (7.0)	41 (4.0)	**0.128**	197 (6.5)	41 (4.0)	**0.109**
Other	4636 (3.1)	46 (4.5)	0.076	73 (2.4)	46 (4.5)	**0.117**
Unknown	16 052 (10.7)	83 (8.2)	0.086	294 (9.7)	83 (8.2)	0.052
BMI, mean (SD)	30.58 (6.47)	29.48 (6.07)	**0.175**	29.22 (5.96)	29.48 (6.07)	0.044
BMI, median (range)	29.7 (10.0–168.1)	28.6 (18.0–65.5)	N/A	28.3 (16.0–68.6)	28.5 (18.0–65.5)	N/A
Preoperative variables						
Functional status (dependent), n (%)	2334 (1.6)	3 (0.3)	**0.132**	33 (1.1)	3 (0.3)	0.095
Outpatient, n (%)	76 286 (50.9)	722 (71.2)	**0.426**	2159 (71.0)	722 (71.2)	0.005
Smoker within 1 year, n (%)	29 535 (19.7)	184 (18.1)	0.039	639 (21.0)	184 (18.1)	0.072
Steroid use, n (%)	5777 (3.9)	33 (3.3)	0.032	107 (3.5)	33 (3.3)	0.015
Weight loss, n (%)	353 (0.2)	3 (0.3)	0.012	5 (0.2)	3 (0.3)	0.027
Diabetes, n (%)	25 994 (17.3)	118 (11.6)	**0.162**	408 (13.4)	118 (11.6)	0.054
Dyspnea, n (%)	6260 (4.2)	21 (2.1)	**0.121**	106 (3.5)	21 (2.1)	0.086
COPD, n (%)	5259 (3.5)	25 (2.5)	0.061	75 (2.5)	25 (2.5)	0.000
Heart failure, n (%)	411 (0.3)	0 (0.0)	0.074	6 (0.2)	0 (0.0)	0.063
Hypertension, n (%)	74 175 (49.5)	398 (39.3)	**0.206**	1207 (39.7)	398 (39.3)	0.009
Dialysis, n (%)	313 (0.2)	3 (0.3)	0.017	3 (0.1)	3 (0.3)	0.044
Disseminated cancer, n (%)	444 (0.3)	1 (0.1)	0.044	5 (0.2)	1 (0.1)	0.018
Bleeding disorder, n (%)	2126 (1.4)	11 (1.1)	0.030	27 (0.9)	11 (1.1)	0.020
Open wound/wound infection, n (%)	481 (0.3)	2 (0.2)	0.024	7 (0.2)	2 (0.2)	0.007
Preoperative blood transfusion, n (%)	123 (0.1)	0 (0.0)	0.041	1 (0.0)	0 (0.0)	0.026
Operative variables						
ASA class, n (%)						
1	9764 (6.5)	123 (12.1)	**0.194**	382 (12.6)	123 (12.1)	0.013
2	77 111 (51.4)	607 (59.9)	**0.171**	1779 (58.5)	607 (59.9)	0.028
3	59 989 (40.0)	274 (27.0)	**0.277**	852 (28.0)	274 (27.0)	0.022
4	2981 (2.0)	8 (0.8)	**0.103**	25 (0.8)	8 (0.8)	0.004
5	8 (0.0)	1 (0.1)	0.041	1 (0.0)	1 (0.1)	0.026
Not assigned	143 (0.1)	1 (0.1)	0.001	3 (0.1)	1 (0.1)	0.000
Wound class 1 or 2, n (%)	149 239 (99.5)	1011 (99.7)	0.033	3033 (99.7)	1011 (99.7)	0.000
Mean operative time (SD)	111.7 (71.4)	79.9 (52.3)	**0.508**	97.9 (60.7)	79.9 (52.3)	**0.317**
Median operative time (range)	93 (1–1165)	64 (16–444)	N/A	82 (9–654)	66 (16–444)	N/A
Emergency, n (%)	2662 (1.8)	12 (1.2)	0.049	30 (1.0)	12 (1.2)	0.019

*Boldface type indicates imbalance on demographics (SMD>0.1).
ASA, American Society of Anesthesiologists; SMD, standardized mean difference.

vs 1.1±3.8 days; p<0.001) and PS-matched comparisons (1.3±3.0 days vs 1.1±3.8 days; p<0.001). There were no significant differences in other complications between the groups on either the unadjusted or PS-matched comparisons.

In unadjusted analysis, RA was associated with significantly lower odds of readmission (OR:0.57, 95% CI 0.38 to 0.84, p=0.005), any complication (OR:0.43, 95% CI 0.30 to 0.62, p<0.0001) and shorter length of hospital stay (−1.5, 95% CI −1.7 to −1.4, p<0.001). In adjusted analysis using the PS as a covariate, RA was associated with fewer complications (parameter estimate: −0.43, 95% CI −0.81 to −0.06, p=0.02) and shorter length of hospital stay (parameter estimate: −0.76, 95% CI −0.90 to −0.63, p<0.001). There was no statistically significant association between anesthetic type and readmission (parameter estimate: −0.34, 95% CI −0.74 to 0.05, p = 0.09) (table 3).

DISCUSSION

In this retrospective population-based analysis, we found that compared with GA, RA was associated with fewer complications, less blood transfusion and shorter LOS after lumbar spine surgery. Although statistically significant, the absolute magnitude of these effects was small, and of uncertain clinical significance.

Clinical and population-based studies which investigate the impact of anesthetic technique on outcomes after lumbar spine surgery are sparse and results are conflicting. There are three systematic reviews with meta-analysis of prospective clinical trials comparing outcomes between RA and GA for lumbar spine surgery. The earliest included eight studies (625 patients) and found that patients who received RA required less analgesia in postanesthesia care unit (PACU) and had less nausea and vomiting (PONV) over the first postoperative day but found no

Table 2 Postoperative complications, length of stay and discharge destination

	Unmatched			Matched		
Variable	General anesthesia (n=1 49 996)	Regional anesthesia (n=1014)	P value*	General anesthesia (n=3042)	Regional anesthesia (n=1014)	P value*
Complications, n(%)						
Any postoperative complication	8602 (5.7)	25 (2.5)	<0.0001	110 (3.6)	25 (2.5)	0.085
Superficial wound infection	1328 (0.9)	8 (0.8)	1.000	17 (0.6)	8 (0.8)	0.486
Deep wound infection	648 (0.4)	2 (0.2)	0.824	5 (0.2)	2 (0.2)	1.000
Organ space infection	474 (0.3)	0 (0.0)	0.056	4 (0.1)	0 (0.0)	0.578
Wound dehiscence	307 (0.2)	2 (0.2)	0.506	3 (0.1)	2 (0.2)	0.604
Pneumonia	526 (0.4)	4 (0.4)	0.803	5 (0.2)	4 (0.4)	0.240
Unplanned intubation	252 (0.2)	2 (0.2)	0.724	1 (0.0)	2 (0.2)	0.156
Deep-vein thrombosis	592 (0.4)	0 (0.0)	**0.017**	7 (0.2)	0 (0.0)	0.204
Failure to wean from ventilator	147 (0.1)	1 (0.1)	1.000	0 (0.0)	1 (0.1)	0.250
Pulmonary embolism	430 (0.3)	0 (0.0)	0.085	6 (0.2)	0 (0.0)	0.347
Renal insufficiency	104 (0.1)	0 (0.0)	1.000	5 (0.2)	0 (0.0)	0.341
Acute renal failure	84 (0.1)	0 (0.0)	1.000	0 (0.0)	0 (0.0)	--
Urinary tract infection	1377 (0.9)	6 (0.6)	0.166	20 (0.7)	6 (0.6)	1.000
Stroke	146 (0.1)	0 (0.0)	0.631	5 (0.2)	0 (0.0)	0.341
Cardiac arrest	111 (0.1)	0 (0.0)	1.000	0 (0.0)	0 (0.0)	--
Myocardial infarction	256 (0.2)	1 (0.1)	1.000	5 (0.2)	1 (0.1)	1.000
Bleeding transfusion	3286 (2.2)	3 (0.3)	<0.0001	40 (1.3)	3 (0.3)	**0.004**
Sepsis	724 (0.5)	2 (0.2)	0.195	11 (0.4)	2 (0.2)	0.538
Septic shock	139 (0.1)	0 (0.0)	0.633	2 (0.1)	0 (0.0)	1.000
Reoperation	3682 (2.5)	14 (1.4)	**0.034**	51 (1.7)	14 (1.4)	0.567
30-day mortality	206 (0.1)	1 (0.1)	1.000	2 (0.1)	1 (0.1)	1.000
Readmission	6034 (4.0)	25 (2.5)	**0.002**	74 (2.4)	25 (2.5)	1.000
Length of hospital stay, mean (SD)	1.9 (3.4)	1.1 (3.8)	<0.0001	1.3 (3.0)	1.1 (3.8)	<0.0001
Length of hospital stay, median (range)	1.0 (0.0–122.0)	0 (0.0–92.0)	N/A	1.0 (0.0–92.0)	0 (0.0–92.0)	N/A
Discharge destination, n(%)						
Home	138 044 (92.0)	966 (95.3)	0.122	2902 (95.4)	966 (95.3)	0.863
Non-home	11 755 (7.8)	46 (4.5)	<0.0001	139 (4.6)	46 (4.5)	1.000
Rehab	5672 (3.8)	23 (2.3)	**0.002**	69 (2.3)	23 (2.3)	1.000
Skilled care	5657 (3.8)	21 (2.1)	**0.001**	65 (2.1)	21 (2.1)	1.000
Separate acute care	341 (0.2)	2 (0.2)	1.000	4 (0.1)	2 (0.2)	0.644
Unskilled facility, not home	85 (0.1)	0 (0.0)	1.000	1 (0.0)	0 (0.0)	1.000
Expired	84 (0.1)	0 (0.0)	1.000	1 (0.0)	0 (0.0)	1.000
Unknown	113 (0.1)	2 (0.2)	<0.0001	0 (0.0)	2 (0.2)	0.063

*Fisher's exact test was used for dichotomous and categorical variables; Mann-Whitney (Wilcoxon rank-sum) test was used for continuous variables. Boldface type indicates significance at p<0.05.

differences in intraoperative hypotension, bradycardia, blood loss or surgical duration between RA and GA.[7] In the second, Zorrilla-Vaca *et al* included 15 studies (961 patients) and found several benefits of RA compared with GA, including lower incidence of PONV, shorter LOS and less blood loss. However, they did not find effects of anesthetic technique on early pain scores, analgesic requirements or incidence of urinary retention.[8] The most recent analysis included 11 studies (896 patients) and concluded that RA did decrease early postoperative pain and analgesic requirements in the PACU, confirmed the reduction in PONV, and did not find effects on urinary retention, intraoperative bradycardia or hypotension.[9] Importantly, each of these reviews found that the quality of informing trials was overall low with high or very high risk of bias. This may be explained in part by the small number of studies conducted, to date, and also to significant issues of blinding in any study which compares RA to GA.

Data derived from population-based studies may help to overcome some of the methodological and blinding limitations associated with the prospective studies of comparative anesthetic technique. Additionally, the large number of available patient samples should theoretically aid detection of rare events and complications after a relatively safe surgery, such as lumbar decompression/fusion. Unfortunately, as for the clinical studies, population-based data on the topic are limited, and conflicting. The first of two available analyses derived from ACS-NSQIP compared outcomes after lumbar spine surgery among patients who received general or non-GA.[10] The authors concluded equivalent outcomes for LOS, readmission and overall complications between the techniques. The second study reported trends

Table 3 Sensitivity and adjusted analyses

Unadjusted				
Outcome variables*	**OR**	**P value**	**Lower 95%**	**Upper 95%**
Readmission	0.57	0.005	0.38	0.84
Complication	0.43	<0.0001	0.30	0.62
Outcome variable†	**Parameter estimate**	**P value**	**Lower 95%**	**Upper 95%**
Length of hospital stay	−1.53	<0.0001	−1.68	−1.39
Adjusted, with Propensity Score as a covariate				
Outcome variables†	**Parameter estimate**	**P value**	**Lower 95%**	**Upper 95%**
Readmission	−0.34	0.090	−0.74	0.05
Complication	−0.43	0.023	−0.81	−0.06
Length of hospital stay	−0.76	<0.0001	−0.90	−0.63

*Logistic regression was used.
†Generalized linear modeling was used.

in use of GA and non-GA for all types of spine surgery (lumbar, thoracic and/or cervical) between 2005 and 2019.[11] The authors found progressive utilization of RA over time for all subtypes of spine surgery as well as shorter LOS and lower readmission and 30-day complications among patients undergoing lumbar surgery. Discrepancies between the results of the former and present studies may be explained by our attempts to control for the retrospective, observational nature of our design by using PS matching.

Despite our efforts to rigorously PS match patients between the two techniques, we noted a small persistent imbalance in surgical duration between the groups. One interpretation of this is that medically and surgically complex patients were more likely to be offered GA, leading to increased operating time in this group. Although possible, this explanation is less likely when considering that we found no differences in other indices of medical complexity (including BMI, ASA class and age) between the groups. Interestingly, we did find a lower incidence of blood transfusion between RA and GA, both before and after PS matching. Although speculative, lower intraoperative blood losses may have facilitated operating conditions, eliminated the time otherwise required to complete intraoperative transfusion and led directly to shorter surgical duration.

Effects of anesthetic technique on blood loss and transfusion after spine surgery have yielded conflicting results. Most[3 4 6 8] but not all[5 7 10] prior studies concluded that RA was associated with less blood loss compared with GA for spine surgery, possibly due to sympathectomy and consequent intraoperative hypotension. It is possible that other improvements in perioperative blood management could account for differences in the incidence of transfusion between the anesthetic techniques found here, specifically, use of tranexamic acid.[15 16] This was not controlled for in the present analysis due to limitations in data recording and extraction from the NSQIP datasets.

There are several unique risks of RA for spine surgery, which should be considered prior to final selection of anesthetic technique. Important considerations include prone positioning in the obese patient and patients with difficult airways; plans for unanticipated lengthy surgical duration, complication, suboptimal spinal anesthetic or patient intolerance of sedation/positioning; risk of postdural puncture headache, epidural–spinal hematoma or neurologic injury/neuropraxia; and what to do in the event of motor weakness/sensory loss in the PACU beyond the expected duration of the spinal anesthetic. Careful patient selection, planning and consensus between anesthetic and surgical teams are likely to be key to successful outcomes using RA. Provocatively, reports from the surgical literature describing 'awake spine surgery' are emerging, and, in contrast to the present results, are suggested to offer profound benefits for patient satisfaction and other important outcomes—despite mainly comprizing case series, small cohort studies and/or institutional experiences.[17–19] Furthermore, these reports tend to extoll the benefits of spinal anesthesia in combination with regional analgesia techniques—which likewise have not been fully investigated or associated with significant benefits on recovery after lumbar spine surgery.[20 21] 'Awake spine surgery' reports tend to be from surgeon-led teams and lack important definitions of terms (crucially, what it means to be 'awake') details (of sedation, if given, complications and conversion to GA) methods for patient selection[22] and assume that patients who receive RA for spine surgery are, defacto, also awake.[2 11] These differences may account (at least in part) for differences in outcomes reported in the 'awake spine surgery' studies and those reported here.

Strengths and limitations

Our study includes data derived from a range of institutions and includes a large sample of patients, which we carefully matched for analyses. Accordingly, the sample is likely to be representative of the broader population. However, there are several limitations to our study. First, the work is based on a US data set and may not be generalizable to other patient populations or practice settings. Second, as for any study using ACS-NSQIP, coding errors could lead to misclassification of patients, surgeries and anesthetic type. The latter is particularly relevant for the current study, given the rarity with which RA is performed for spine surgery. Allied to this, we included 171 patients in the GA group who had also received RA: whether this represented failed neuraxial anesthesia, a planned combined anesthetic regimen or coding error is unknown. Third, some clinically important data which may guide anesthetic selection and influence the outcomes are not available from ACS-NSQIP. Examples include details of the GA and sedation for RA (if provided); the depth of sedation of patients receiving RA; history of difficult intubation or coagulopathy and surgeon preferences for anesthetic choice.

CONCLUSIONS

This analysis of ACS-NSQIP data found few benefits of RA compared with GA on outcomes after lumbar spine surgery. RA was associated with fewer complications, lower incidence of blood transfusion and shorter LOS, but the magnitude of these effects was small and of uncertain clinical significance. Of note, we did not find any benefits of GA over RA for any individual complications or other outcomes of interest, suggesting either technique may be considered in appropriate patients. We caution in interpretation of these results, given the small proportion of patients who received RA, and paucity of prospective data on technique-specific risks and benefits for patients undergoing spine surgery. Subject to these caveats, the results presented here suggest that RA may be a modifiable factor to improve outcomes after lumbar spine surgery.

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Supplemental Table 1. CPT Code Descriptions

CPT Codes	Descriptions
22102	Partial Excision of Posterior Vertebral Component (e.g. Spinous Process, Lamina or Facet) for Intrinsic Bony Lesion, Single Vertebral Segment
62380	Endoscopic Decompression of the Spinal Cord or Nerve Roots at the Lumbar Level
63005	Laminectomy with Exploration and/or Decompression of Spinal Cord and/or Cauda Equina, without Facetectomy, Foraminotomy or Discectomy (e.g. Spinal Stenosis), 1 or 2 Vertebral Segments; Lumbar, except for Spondylolisthesis
63011	Laminectomy with Exploration and/or Decompression of Spinal Cord and/or Cauda Equina, without Facetectomy, Foraminotomy or Discectomy (e.g. Spinal Stenosis), 1 or 2 Vertebral Segments; Sacral
63012	Laminectomy with Removal of Abnormal Facets and/or Pars Inter-Articularis with Decompression of Cauda Equina and Nerve Roots for Spondylolisthesis, Lumbar (Gill Type Procedure)
63017	Laminectomy with Exploration and/or Decompression of Spinal Cord and/or Cauda Equina, without Facetectomy, Foraminotomy or Discectomy (e.g. Spinal Stenosis), more than 2 Vertebral Segments; Lumbar
63030	Laminotomy (Hemilaminectomy), with Decompression of Nerve Root(s), Including Partial Facetectomy, Foraminotomy and/or Excision of Herniated Intervertebral Disc; 1 Interspace, Lumbar
63047	Laminectomy, Facetectomy and Foraminotomy (Unilateral or Bilateral with Decompression of Spinal Cord, Cauda Equina and/or Nerve Root[s], [e.g. Spinal or Lateral Recess Stenosis]), Single Vertebral Segment; Lumbar
63056	Transpedicular Approach with Decompression of Spinal Cord, Equina and/or Nerve Root(s) (e.g. Herniated Intervertebral Disc), Single Segment
63035	Laminotomy (Hemilaminectomy), with Decompression of Nerve Root(s), Including Partial Facetectomy, Foraminotomy and/or Excision of Herniated Intervertebral Disk; Each Additional Interspace, Cervical or Lumbar
63048	Laminectomy, Facetectomy and Foraminotomy (Unilateral or Bilateral with Decompression of Spinal Cord, Cauda Equina and/or Nerve Root[S], [e.g. Spinal or Lateral Recess Stenosis]), Single Vertebral Segment; Each Additional Segment, Cervical, Thoracic, or Lumbar
63057	Transpedicular Approach with Decompression of Spinal Cord, Equina and/or Nerve Root(s) (e.g. Herniated Intervertebral Disc), Single Segment
0275T	Percutaneous Laminotomy/Laminectomy (Intralaminar Approach) for Decompression of Neural Elements