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Sleep Apnea and Total Joint Arthroplasty under Various Types of Anesthesia:

A Population-Based Study of Perioperative Outcomes

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Abstract

Background and Objectives—The presence of sleep apnea (SA) among surgical patients has been associated with significantly increased risk of perioperative complications. Although regional anesthesia has been suggested as a means to reduce complication rates among SA patients undergoing surgery, no data are available to support this association. We studied the association of the type of anesthesia and perioperative outcomes in patients with SA undergoing joint arthroplasty.

Methods—Drawing on a large administrative database (Premier Inc), we analyzed data from approximately 400 hospitals in the United States. Patients with a diagnosis of SA who underwent primary hip or knee arthroplasty between 2006 and 2010 were identified. Perioperative outcomes were compared between patients receiving general, neuraxial, or combined neuraxial-general anesthesia.

Results—We identified 40,316 entries for unique patients with a diagnosis for SA undergoing primary hip or knee arthroplasty. Of those, 30,024 (74%) had anesthesia-type information available. Approximately 11% of cases were performed under neuraxial, 15% under combined neuraxial and general, and 74% under general anesthesia. Patients undergoing their procedure under neuraxial anesthesia had significantly lower rates of major complications than did patients who received combined neuraxial and general or general anesthesia (16.0%, 17.2%, and 18.1%, respectively; $P = 0.0177$). Adjusted risk of major complications for those undergoing surgery under neuraxial or combined neuraxial-general anesthesia compared with general anesthesia was also lower (odds ratio, 0.83 [95% confidence interval, 0.74–0.93; $P = 0.001$] vs odds ratio, 0.90 [95% confidence interval, 0.82–0.99; $P = 0.03$]).

Conclusions—Barring contraindications, neuraxial anesthesia may convey benefits in the perioperative outcome of SA patients undergoing joint arthroplasty. Further research is needed to

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enhance an understanding of the mechanisms by which neuraxial anesthesia may exert comparatively beneficial effects.

The presence of sleep apnea (SA) among patients undergoing surgery has been associated with significantly increased risk of perioperative complications.[1–3] The impact of this problem is compounded by the increasing prevalence of the disease, which is estimated to affect as many as one-fourth of patients presenting for surgery.[3,4] Despite this challenge, no proven interventions to reduce complication rates among SA patients are available, and even the impact of perioperative use of positive airway pressure remains equivocal.[1,2] In an attempt to reduce the risk for adverse outcomes among surgical patients with SA, the current American Society of Anesthesiology practice advisory recommends the use of regional anesthesia.[5] However, no data are available to support this approach. Although we have previously studied outcomes in patients with SA[3] using a different database (National Inpatient Sample), this data source did not allow for the study of the impact of the type of anesthesia on outcomes. In addition, this patient group is of particular interest as (1) the type of surgery allows for the utilization of a number of different anesthetic approaches, and (2) the prevalence of SA among orthopedic patients is high compared with other surgical populations.[3] Therefore, we sought to study the impact of the type of anesthesia on perioperative outcomes in SA patients undergoing joint arthroplasty using large-scale, population-based data. We hypothesized that the use of neuraxial or a combination of neuraxial and general anesthesia would be associated with more beneficial perioperative outcomes in SA patients undergoing primary hip or knee arthroplasty compared with general anesthesia.

METHODS

Data Source, Ethics Approval

Data collected between 2006 and 2010 from an administrative database (Premier Inc, Charlotte, North Carolina) containing discharge information from approximately 400 acute care hospitals located throughout the United States were used for this study.[6] The Premier database provides specific and granular information about present diagnoses and procedures carried out during inpatient visits. Data integration is strictly regulated and controlled via rigorous data validation assurance procedures. This study was exempt from consent requirements by the Hospital for Special Surgery Institutional Review Board as data are deidentified and in accordance with the Health Insurance Portability and Accountability Act. [7] The same data set was used previously by our group for various other projects, including the evaluation of rates of critical care utilization in patients receiving total joint arthroplasty[8] and differential outcomes in patients undergoing unilateral hip or knee[9] or bilateral total knee arthroplasty.[10] However, it had not been used to evaluate the impact of anesthesia-specific information on outcomes in SA patients undergoing hip and knee arthroplasty.

Study Sample

Data were included in the study cohort if patients had (1) *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) procedure codes for primary total hip or knee arthroplasty (81.51; 81.54) and (2) an *ICD-9-CM* code for SA (786.03, 780.51, 780.53, 780.57, 327.20–327.27, 327.29). Patients included were admitted between December 2005 and September 2010 to a participating institution. Of those, 2617 patients (8%) had multiple procedures and were excluded from analysis. Utilizing information provided in billing data, the cohort was subdivided into 3 groups according to the type of anesthesia received: (1) general, (2) neuraxial, and (3) combined neuraxial and general anesthesia. Patients who could not be allocated to these groups were excluded from the analysis. The influence of this exclusion on outcomes was assessed by performing a sensitivity analysis by including patients without a designation for anesthesia type (ie, “others”) in the regression analysis. Patients receiving a peripheral nerve block in addition to their primary anesthetic, as identified by billing codes, were included in the study sample and were allocated to the respective primary anesthesia-type groups. The proportion of patients who had only peripheral nerve blocks listed as an anesthetic was less than 1%, and entries were added to the “others” category.

Demographic Variables

Patient characteristics were compared among anesthesia groups. Demographic variables included age, sex, ethnicity (white, African American, Hispanic, other), and procedure type (primary hip or knee arthroplasty). The prevalence of individual comorbidities and overall comorbidity burden was assessed using the method described by Deyo et al.[11] The prevalence of comorbid conditions was determined using *ICD-9* codes. Age and comorbidity burden were also evaluated as both categorical and continuous variables.

Complication Variables

Cases with major complications were identified by the presence of respective *ICD-9-CM* diagnoses and billing codes (as listed in Appendix 1). Thirty-day mortality rate was defined as any cases of death within 30 days during any admission. This information was provided by Premier Inc’s discharge status data. Major individual complications included deep venous thrombosis, pulmonary embolism, cerebrovascular event, pulmonary complications, cardiac complications (except myocardial infarction), pneumonia, all infections, acute renal failure, gastrointestinal complications, acute myocardial infarction, and 30-day mortality. A combined complications variable was defined as incurring 1 or more of the major complications listed above. Moreover, a cardiac complications variable (consisting of acute myocardial infarction and cardiac complications other than myocardial infarction) and a pulmonary complications variable (consisting of pulmonary complications, pneumonia, and pulmonary embolism) were established as separate outcomes.

In addition, the incidence of blood product transfusion, mechanical ventilation, and critical care service utilization was computed by identifying appropriate *ICD-9-CM* or billing codes (Table 3). Differences in length of hospital stay and cost of hospitalization were analyzed as continuous variables and as binary variables dichotomized based on the 75th percentile. Entries above the 75th percentile were categorized as prolonged hospitalizations or increased cost of hospitalization, respectively.

Statistical Analysis

The study goal was to analyze if the type of anesthesia is associated with differences in perioperative outcomes. All statistical analyses were performed using SAS version 9.3 (SAS Institute, Cary, North Carolina). To facilitate analysis of weighted data, SAS procedures SURVEYMEANS, SURVEYFREQ, SURVEYREG, and SURVEYLOGISTIC were utilized for descriptive analyses and modeling efforts.

Univariate Analysis

Weighted means and 95% confidence intervals (CIs) were described for continuous variables with nonskewed distributions, and medians and interquartile ranges (IQRs) were described for variables with skewed distributions. One-way analysis of variance F test or nonparametric Kruskal-Wallis test, whenever applicable, was used to compare means or medians for continuous variables among more than 2 groups.

Unweighted frequency and weighted percentages were reported for categorical variables. A χ^2 test was performed to evaluate the association of 2 categorical variables.

Multivariate Regression Analysis

Binary outcomes of incidence of combined major complications, pulmonary complications, cardiac complications, use of blood product transfusion, need for mechanical ventilation, utilization of critical care services, prolonged length of hospital stay, and increased cost of hospitalization as defined above were considered. For each outcome, a weighted logistic regression was used to evaluate its association with the type of anesthesia while controlling for age group, sex, ethnicity, Deyo Index group, and type of surgery. These adjustments were included in the final model because they were considered clinically relevant or had $P < 0.2$ in the univariate analyses. As a secondary analysis, we added peripheral nerve block as a covariate to evaluate its independent influence on outcomes using the same regression model. Odds ratios, 95% CI, and *P* values were reported from the multivariate analysis. The conventional threshold of statistical significance (ie, 2-sided $P < 0.05$) was used to determine significance of variables. However, because pairwise comparisons were performed, the issue of multiplicity adjustment may be a concern. Readers may wish to evaluate statistical significance at a modified α level of 0.05/3 comparisons = 0.0167 based on the Bonferroni correction. Under this α level, statistical significance was achieved when $P < 0.0167$ for a given group comparison.

The influence of “other” type of anesthesia was assessed by performing a sensitivity analysis in the multivariate regression analysis: once by including and once by excluding “others” entries,[12] where “others” entries were treated as a separate group.

Model discrimination and calibration were performed by using the C-statistic and the Hosmer-Lemeshow (H-L) test,[13] respectively. The C-statistic, representing the area under the receiver operating characteristic curve, measures the level of model discrimination between observed data at different levels of the outcome. Whereas a C-statistic of 0.7 or above was considered acceptable, it has been suggested that in the setting of large database research a low C-statistics was not a result of a weak model, but rather a consequence of patient entries in cohorts simply becoming more alike.[14] The H-L test was performed so that the probability predictions from the model reflected the true occurrence of events in the data. Nonsignificant *P* values from the H-L test were considered a well-calibrated model; however, significant *P* values could claim adequate calibration when applied to large numbers of patients.[15]

RESULTS

We identified a total of 40,316 entries for unique patients with a diagnosis for SA who underwent hip or knee arthroplasty. Of those, 30,024 (74%) had a listing for the type of anesthesia received and were included into the analysis. Approximately 11% of cases were performed under neuraxial, 15% under combined neuraxial and general, and 74% under general anesthesia. The frequencies for the use of peripheral nerve blocks were 8%, 1%, and 1.5% in the general, neuraxial, and general/neuraxial anesthesia group, respectively.

Patient-related demographics are presented in Table 1. Patients who underwent surgery under neuraxial anesthesia were on average older than those in the neuraxial/general or general groups. No difference was found in the prevalence of various comorbidities between groups (Fig. 1) or in the distribution of Deyo comorbidity categories (Table 1). Patients undergoing their procedure under neuraxial anesthesia had significantly lower rates of major complications compared with those undergoing surgery under neuraxial/general or general anesthesia (16.0%, 17.2%, and 18.1%; $P = 0.0177$). Rates of pulmonary, gastrointestinal,

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and infectious complications as well as acute renal failure in particular were higher in those undergoing surgery involving a general anesthetic compared with a neuraxial approach (Table 2). Utilization of transfusions, mechanical ventilation, and critical care services was significantly lower in the neuraxial and neuraxial/general groups than in the general anesthesia group. Patients in the neuraxial and general/neuraxial groups had shorter medians of lengths of hospitalizations compared with the general group (2.6 [IQR, 2.2–3.3], 2.6 [IQR, 2.2–3.6], 2.8 [IQR, 2.3–3.6]; $P < 0.001$). Median costs of care were US $15,827 (IQR, US $13,292–$18,743) for the neuraxial, US $15,357 (IQR, US $13,132–$18,192) for the neuraxial/general, and US $15,345 (IQR, US $12,551–$19,335) for the general anesthesia group, respectively ($P < 0.001$).

There were no significant odds ratio (OR) estimate differences in the sensitivity analysis with or without missing data of type of anesthesia. When controlling for covariates, the odds for combined major complications were lower among patients receiving neuraxial anesthesia compared with general anesthesia (Table 3). The same was true when specifically looking at the outcome of pulmonary complications, but the type of anesthesia had no effect on the risk for cardiac complications, respectively (Table 3).

Furthermore, the odds for the outcomes of utilization of mechanical ventilation, requirement for critical care services, prolonged length of stay, and increased cost were also beneficially associated with neuraxial versus general anesthesia (Table 3). No difference was found for the odds of requiring blood transfusions between neuraxial and general anesthesia.

When entering the presence or absence of a peripheral nerve block into the regression models, the use of a peripheral nerve block was not associated with any significant impact on the outcomes of combined, pulmonary, and cardiac complications (OR, 0.95 [CI, 0.85–1.06; $P = 0.3661$]; OR, 0.93 [CI, 0.74–1.16; $P = 0.4989$]; OR, 1.11 [CI, 0.96–1.28; $P = 0.1596$]) or need for transfusion (OR, 1.03 [CI, 0.92–1.17; $P = 0.1596$]), respectively.

However, decreased odds for the need of mechanical ventilation, critical care services, and prolonged length of stay were seen, respectively (OR 0.66 [CI, 0.51–0.86; $P = 0.0018$]; OR, 0.46 [CI, 0.36–0.57; $P < 0.0001$]; OR, 0.84 [CI, 0.77–0.92; $P < 0.0001$]). The odds for increased cost above the 75th percentile for those with a peripheral nerve block were increased (OR, 1.4 [CI, 1.28–1.53; $P < 0.0001$]).

The C-statistic ranged from 0.6 to 0.7. The H-L tests showed nonsignificant *P* values for all models except for those with the outcomes mechanical ventilation and utilization of critical care services.

DISCUSSION

In this population-based study, we were able to show differential perioperative outcomes in patients with a diagnosis of SA who undergo hip or knee arthroplasty procedures under neuraxial versus general anesthesia. Patients with SA who received a neuraxial versus a general anesthetic for their surgery had reduced odds for major complications, requirement for mechanical ventilation, and intensive care services, as well as decreased odds for prolonged hospitalization and increased cost. Therefore, without proving a causal relationship, our results suggest potential beneficial associations of the use of regional anesthesia in SA patients with regard to perioperative complication incidence and risk. To the best of our knowledge, this is the first large-scale, population-based study to describe these associations.

We found significant discrepancies in the utilization of the various anesthesia types among patients with SA. Only one-fourth of patients received a neuraxial anesthetic with or without a concomitant general technique. The lower utilization of regional anesthesia among the orthopedic patient populations has previously been identified in our study of unilateral hip and knee and bilateral knee arthroplasty recipients.[9,10] Although the choice of anesthetic technique may vary by, among other reasons, regional custom, anesthesiologist's and surgeon's preference, and patient wishes, the low rate of utilization found in this study is surprising. Given the fact that hip and knee arthroplasties are amenable to regional anesthesia and that the American Society of Anesthesiologists advisory on the perioperative and postoperative management of patients with SA has identified regional anesthesia as a preferred anesthetic option for these patients,[5] a higher rate of utilization might have been expected. Moreover, patients in whom epidural analgesia or peripheral nerve blocks have been applied intraoperatively were recently shown to exhibit lower postoperative opioid-related distress scores.[16]

We identified favorable odds in regard to complications, resource utilization, and cost among patients receiving neuraxial versus general anesthesia in this study. A potentially beneficial influence of regional anesthesia on perioperative outcomes after orthopedic surgery has previously been reported in a number of meta-analyses.[17–19] However, outcomes studied were limited, and benefits were shown mostly related to reduced blood loss and effects on thromboembolic events. Unfortunately, these reports are limited by a number of factors including analyses of studies with relatively small sample sizes, representation of experiences of specialized centers, and inclusion of investigations that do not reflect recent medical practice.

A further limitation of existing studies is the lack of data on outcomes among subpopulations of patients, which may arguably be affected by different levels of risk for adverse events. In this context, patients with SA have been identified as a group of individuals at especially high risk for perioperative complications, especially those affecting the pulmonary system.[1,3] Reasons for these findings may include the high prevalence of comorbid disease such as obesity and diabetes,[3] higher baseline levels of systemic and pulmonary inflammation that are compounded by perioperative insults,[20] decreased pharyngeal sphincter function thus promoting risk of aspiration,[3,21] and increased sensitivity to the respiratory depressant effects of opioids potentially leading to respiratory compromise.[22] Unlike other studies in orthopedic patients,[18,23] our findings indicate that neuraxial anesthesia confers only insignificantly reduced odds for requirement of blood transfusion in patients with SA when compared with general anesthesia. Evidence regarding reduced need of blood product substitution evoked by neuraxial anesthesia has, however, not remained undisputed. A meta-analysis by Mauermann et al[18] concluded that patients undergoing total hip arthroplasty under neuraxial anesthesia had lower overall odds of receiving blood transfusions (OR, 0.26); however, the very wide CI (0.06–1.05) indicated a high degree of variability within the included studies. Moreover, there are currently no data available on comparative risk for transfusion in patients with SA, a patient population with potentially distinct risk factors for blood loss and transfusion.

In a case-control study including 1016 cases of SA patients and controls, Cashman et al[24] reported no difference in perioperative cardiovascular and respiratory complications following total hip arthroplasty, but a higher incidence of acute renal failure in SA patients. These findings could indicate that awareness for the condition along with a perioperative monitoring and treatment protocols could be capable of, at least to a certain degree, reducing the associated risk.

Although only a secondary outcome, we attempted to identify the independent impact of the addition of a nerve block on outcomes. Although the regression models including this variable were less robust and have to be interpreted accordingly, we found that the addition of a peripheral nerve block did not affect the risk of complications. However, some benefit was seen in regard to the need of mechanical ventilation and use of critical care services. Peripheral nerve blocks may confer better pain control postoperatively and thus may reduce the risk of opioid-related respiratory depression, which may explain our findings to some degree.[16,25,26]

A number of factors must be mentioned as limitations, most of which are related to the nature of data source analysis. First, the Premier Inc database comprises only events that occurred during the index admission in which the surgery was performed; thus, postdischarge events (except 30-day mortality) could not be analyzed. Also, we did not obtain detailed information about a number of clinical events from the database: blood loss, administration of medication (including cardioprotective drugs and anticoagulation agents), and other therapeutic interventions were not taken into account. However, as all of this information is recorded from a variety of clinical settings, our results are based on "real world" practice, rather then presenting conclusions from randomized or controlled circumstances in single academic institutions, as is frequently the case with prospective studies. Furthermore, *ICD-9* coding is used to identify complications in this database (Table 3). In addition, the timing of complication recording may be contingent with institutional practices; that is, the exact occurrence time of the complication within the time of hospital stay cannot be determined. It must also be mentioned that coding errors can occur despite rigorous quality checks by the database vendor. As this confounding factor is equally distributed across the whole data set, the resulting bias is likely of little relevance to comparative results. To ensure accuracy and quality, extensive data validation procedures are performed before distribution. Multiple analyses have been performed and published across a number of specialties, confirming the rigor of the database construct.[27–29]

Moreover, it is not possible to correlate the diagnosis of SA as defined by *ICD-9* code with the severity of the condition. As only patients with a present diagnosis code for SA were identified, the actual incidence of SA is likely considerably higher than reported in this study. It is possible that patients with problematic airways were preferentially managed using general anesthesia. Weingarten et al[30] recently reported that the severity of SA as determined by preoperative polysomnography was not associated with the rate of perioperative complications. However, these results were based on bariatric surgery in fully diagnosed and treated patients, and the authors conclude that this does not necessarily apply to unrecognized and/or untreated SA.[30] In addition, we do not have information on the continuous or perioperative use of positive airway pressure therapy as a therapeutic strategy for SA. The individual risk of either anesthetic technique (neuraxial or general) was not analyzed, including complications such as nerve damage, blood vessel puncture, intubation-related oropharyngeal injury, or failed intubation. However, all of these complications are known to occur with relatively low incidence. Individual contraindications have to be taken into consideration as certain comorbidities can potentially prohibit the use of one or the other technique (for instance, anticoagulation for neuraxial or pulmonary comorbidity for general anesthesia). Although interesting, the combined neuraxial/general anesthesia group poses additional difficulty in interpretation, as patients with failed neuraxial techniques (for instance, those with inadequate intraoperative analgesia) were likely included into this category as well as those with a planned combined approach. Finally, the group of patients who also received a peripheral nerve block in this cohort was relatively small, and no information for the reason for time of placement can be derived from the database. In addition, the subset of patients who received a peripheral nerve block as the only anesthetic for joint arthroplasty was less than 1% and thus not further analyzed in this study.

In conclusion, in this population-based cohort of orthopedic patients with SA, we were able to show that neuraxial anesthesia and combined neuraxial-general anesthesia are associated with improved odds in regard to major perioperative morbidity, resource utilization, and cost, compared with general anesthesia. Therefore, barring any contraindications, neuraxial anesthesia could potentially convey benefits in perioperative outcome of patient with SA undergoing joint arthroplasty. Further research is needed, however, to examine cause and effect of type of anesthesia and outcome and elucidate potential mechanisms by which neuraxial anesthesia may confer beneficial effects compared with the general approach.

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APPENDIX 1. ICD-9-CM Diagnosis Codes for Major Complications

Complications	*ICD-9-CM* Diagnosis Codes
Deep venous thrombosis	451.1, 451.2, 451.8, 451.9, 453.2, 453.4, 453.8, 453.9
Pulmonary embolism	415.1
Cerebrovascular event	433.01, 433.11, 433.21,433.31, 433.81, 433.91, 434.01, 434.11, 434.91, 997.02
Pulmonary complications	514, 518.4, 518.5, 518.81, 518.82

Complications	***ICD-9-CM* Diagnosis Codes**
Cardiac (non–myocardial infarction)	426.0, 427.41, 427.42, 429.4, 997.1, 427.4, 427.3, 427.31, 427.32
Pneumonia	481, 482.00- 482.99, 483,485, 486, 507.0, 997.31, 997.39
All infections	590.1, 590.10, 590.11, 590.8, 590.81, 590.2, 590.9, 595.0, 595.9, 599.0, 567.0 480, 480.0, 480.1, 480.2, 480.8, 480.9, 481, 482.0, 482.1, 482.2, 482.3, 482.30, 482.31, 482.32, 482.39, 482.4, 482.40, 482.41, 482.42, 482.49, 482.5, 482.8, 482.81, 482.82, 482.83, 482.84, 482.89, 482.9, 483, 483.0, 483.1, 483.8, 485, 486, 487, 997.31, 038, 038.0, 038.1, 038.10, 038.11, 038.12, 038.19, 038.2, 038.3, 038.4, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 038.8, 038.9, 790.7, 998.0, 958.4, 998.5, 998.59, 998.89, 785, 785.50, 785.52, 785.59, 999.39, 999.31, 999.3
Acute renal failure	584, 584.5, 584.9
Gastrointestinal complication	997.4, 560.1, 560.81, 560.9, 536.2, 537.3
Acute myocardial infarction	410.XX
Blood transfusion	99.0, 99.01, 99.02, 99.03, 99.04, 99.05, 99.06, 99.07, 99.08, 99.09, (HCPCS codes) P9010, P9011, P9012, P9016, P9017, P9019, P9020, P9021, P9022, P9023, P9031, P9032, P9033, P9034, P9035, P9036, P9037, P9038, P9039, P9040
Mechanical ventilation	93.90, 96.7, 96.70, 96.71, 96.72, (CPT code) 94002, 94656, 94003, 94657

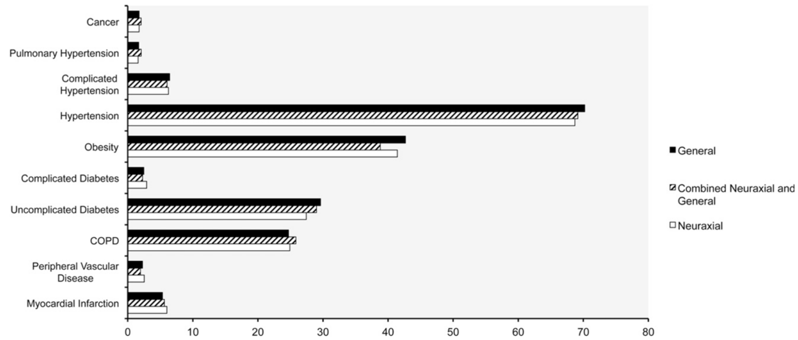

FIGURE 1.

Prevalence of comorbidities. The figure depicts the prevalence (%) of comorbidities among patients by different types of anesthesia. There were no significant differences between groups.

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TABLE 1

Patient- and Procedure-Related Characteristics, Subgrouped by Type of Anesthesia

Patient-Related Demographics	Neuraxial		Neuraxial/General		General		*P*
n	3066	4259	22,699				
%	11.10%	15.30%	73.60%				
Comorbidity burden							
Average Deyo Index (SE)	0.97 (0.92–1.01)	0.99 (0.96–1.03)	1.00 (0.98–1.01)	0.3896			
	n	**%**	**n**	**%**	**n**	**%**	***P***
Deyo Index category							
0	1445	47.5	1964	47.4	10,586	46.5	0.2447
1	661	21.2	858	20.1	4552	20.1	
2	620	20.5	915	20.7	4935	22.0	
≥3	340	10.8	522	11.9	2626	11.4	
Age							
Average age (CI), y	64.2 (63.9–4.6)	63.9 (63.6–64.2)	63.0 (62.9–63.2)	<0.0001			
	n	**%**	**n**	**%**	**n**	**%**	***P***
Age category, y							
<45	54	1.9	92	2.1	570	2.5	<0.0001
45–54	423	14.3	585	14.2	3723	16.5	
55–64	1085	34.5	1525	35.5	8335	36.7	
65–74	1050	34.9	1443	33.4	7249	31.6	
>75	454	14.3	614	14.8	2822	12.6	
Sex							
Female	1404	46.2	1994	46.6	10475	45.8	0.6683
Male	1662	53.8	2265	53.4	12224	54.2	
Ethnicity							
White	2435	82.4	3602	84.2	17893	76.8	<0.0001
African American	144	4.8	289	6.0	1966	7.9	
Hispanic	38	1.0	51	1.3	409	2.1	
Other	449	11.7	317	8.5	2431	13.2	
Procedure type							

Patient-Related Demographics

	Neuraxial		Neuraxial/General		General		*P*
Total hip arthroplasty	672	21.3	1043	24.0	5788	24.8	0.0005
Total knee arthroplasty	2394	78.7	3216	76.0	16911	75.2	
Admission type							
Emergent	13	0.5	135	4.2	680	3.8	<0.0001
Urgent	112	3.8	238	3.9	929	3.9	
Elective	2937	95.6	3882	91.8	21,037	92.0	
Other	4	0.1	4	0.1	53	0.3	

The *P* value indicates testing of the null hypothesis (= no difference across all 3 groups: neuraxial, neuraxial/general, and general): 1-way analysis of variance, Kruskal-Wallis test (for continuous outcomes), χ^2 test (for categorical outcomes).

TABLE 2

Incidence of Major In-hospital Complications, Mortality, and Resource Utilization by Group of Anesthesia

Complications	Neuraxial		Neuraxial/General		General		
	n	%	n	%	n	%	*P*
Deep venous thrombosis	9	0.4	17	0.4	143	0.6	0.1327
Pulmonary embolism	15	0.5	20	0.4	144	0.6	0.1018
Cerebrovascular event	4	0.1	4	0.1	23	0.1	0.9383
Pulmonary complications	49	1.8	79	1.9	475	2.2	0.2622
Cardiac (non–myocardial infarction)	277	9.0	401	9.3	2103	9.2	0.9
Pneumonia	44	1.3	54	1.1	343	1.6	0.0605
All infections	125	3.8	192	4.2	1022	4.6	0.1166
Acute renal failure	82	2.8	125	2.7	701	3.2	0.1172
Gastrointestinal complication	29	0.9	43	0.9	298	1.3	0.0657
Acute myocardial infarction	11	0.4	10	0.2	54	0.2	0.258
Mortality (30-d)	3	0.1	9	0.2	48	0.2	0.2879
Blood transfusion	438	12.7	592	12.4	3230	13.8	0.0273*
Mechanical ventilation	119	2.8	139	2.8	945	4.4	<0.0001*
Critical care services admission	97	3.1	190	4.8	1647	6.9	<0.0001*

(MI = myocardial infarction).

The *P* value indicates testing of the null hypothesis (= no difference across all three groups: neuraxial [N], neuraxial/general [NG], and general [G]): χ^2 test (for categorical outcomes).

*Significant *P* values from post hoc comparisons: for outcome of blood transfusion: $P = 0.0173$(G vs NG); for outcome of mechanical ventilation: $P < 0.0001$ (G vs NG) and $P < 0.001$ (G vs N); for critical care service admission: $P < 0.0001$(G vs NG), $P = 0.0015$ (N vs NG), and $P < 0.001$ (G vs N).

TABLE 3

Results From the Multivariate Regression for Various Outcomes

Multivariate Regression	Neuraxial vs General		Combined Neuraxial/General vs General		Combined Neuraxial/General vs Neuraxial		
Outcome	**OR (95% CI)**	***P*** *	**OR (95% CI)**	***P*** *	**OR (95% CI)**	***P*** *	**C–Statistic**
Combined complications	0.825 (0.74–0.93)	0.0012	0.898 (0.82–0.99)	0.03	1.088 (0.95–1.25)	0.2399	0.64
Pulmonary complications	0.825 (0.65–1.05)	0.1154	0.772 (0.63–0.95)	0.0137	0.935 (0.70–1.26)	0.659	0.63
Cardiac complications	0.904 (0.78–1.05)	0.1859	0.936 (0.83–1.06)	0.3121	1.035 (0.86–1.24)	0.7069	0.70
Blood transfusion	0.919 (0.81–1.04)	0.1776	0.87 (0.78–0.97)	0.0116	0.947 (0.81–1.10)	0.4821	0.64
Mechanical ventilation	0.636 (0.50–0.80)	0.0001	0.644 (0.53–0.79)	<0.0001	1.012 (0.76–1.35)	0.9334	0.59
Critical care service admission	0.433 (0.34–0.55)	<0.0001	0.666 (0.56–0.79)	<0.0001	1.538 (1.16–2.03)	0.0025	0.61
Prolonged length of stay	0.752 (0.69–0.82)	<0.0001	0.70 (0.65–0.76)	<0.0001	0.93 (0.83–1.04)	0.202	0.60
Increased cost of hospitalization	0.883 (0.80–0.98)	0.0139	0.704 (0.64–0.77)	<0.0001	0.797 (0.70–0.90)	0.0004	0.57

General anesthesia is the reference group. Displayed are ORs, 95% CIs, and *P* values. Prolonged length of stay and increased cost of hospitalization are defined as values exceeding the 75th percentile.

* Readers may wish to evaluate statistical significance at a modified α level of 0.05/3 comparisons = 0.0167 (Bonferroni correction). Under this α level, statistical significance is achieved when $P < 0.0167$ for a given group comparison.