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Neuraxial Anesthesia Decreases Postoperative Systemic Infection Risk Compared with General Anesthesia in Knee Arthroplasty

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BACKGROUND: Surgical stress has been shown to result in immune disturbance. Neuraxial anesthesia (NA) has long been hypothesized to blunt undesired surgical insults and thus limit immune compromise and improve surgical outcomes. We hypothesized that NA would decrease postoperative infectious complications compared with general anesthesia (GA) among knee arthroplasty patients.

METHODS: We studied the American College of Surgeons National Surgical Quality Improvement Program database from 2005 to 2010. There were 16,555 patients included in our final cohort, with 9167 patients receiving GA and 7388 patients receiving spinal or epidural anesthesia.. Outcomes of interest included infection-related 30-day postoperative complications, including surgical site–related infections, pneumonia, urinary tract infection, sepsis, septic shock, and a composite end point of any systemic infection. Multivariable logistic regression was performed to test for effect of anesthesia type while adjusting for the influence of preexisting comorbidities.

RESULTS: The overall mortality was 0.24% and 0.15% among NA and GA subjects, respectively ($P = 0.214$). NA subjects had fewer unadjusted incidences of pneumonia ($P = 0.035$) and composite systemic infection ($P = 0.006$). After risk adjustment for preexisting comorbidities, NA was associated with lower odds of pneumonia (odds ratio = 0.51 [95% confidence interval, 0.29–0.90]) and lower odds of composite systemic infection (odds ratio = 0.77 [95% confidence interval, 0.64–0.92]).

CONCLUSIONS: Our study suggested that NA was associated with lower adjusted odds of both pneumonia and a composite outcome of any systemic infectious complication within 30 days of surgery compared with GA. (Anesth Analg 2013;117:1010–6)

There are more than 500,000 total knee arthroplasty procedures performed annually in the United States, and the total number of cases is increasing every year.[1] Most of these knee arthroplasty candidates are elderly, and some have extensive coexisting cardiac, pulmonary, and other systemic diseases.[2]

Surgical stress and anesthesia result in various metabolic and endocrine disturbances and may lead to generalized immune suppression.[3–6] Neuraxial anesthesia (NA), including spinal and/or epidural anesthesia, reduces the surgical stress response.[7,8] It has long been hypothesized that NA may reduce complications and improve surgical outcomes by blocking noxious afferent inputs and decreasing surgery-related disturbance.[9,10] These effects of NA, particularly those on the immune response, might have a profound effect on the risk of infectious complications. Nonetheless, while prior studies have suggested that NA is beneficial among selected patient groups,[11–15] the small sample sizes preclude firm conclusions regarding the association of anesthesia type and infectious complications.

In this study, we focused on knee arthroplasty, which is one of the most common and painful procedures regularly performed with general anesthesia (GA) and/or NA worldwide. We hypothesized that NA would decrease postoperative infectious complications compared with GA among knee arthroplasty patients. Drawing on a prospectively collected and validated clinical database, we compared rates of pneumonia, urinary tract infection, sepsis, septic shock, surgical site infections, and a composite outcome of any systemic infectious events according to anesthesia type.

METHODS

Data Source

This study was exempted by the IRB of the University of Pennsylvania (Philadelphia, PA). We acquired the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database from 2005 to 2010 (http://site.acsnsqip.org). NSQIP is a nationally validated, risk-adjusted, outcome-based program to measure surgical outcomes. NSQIP collects data from a patient's medical chart, as opposed to many large database studies, which use administrative and claims data from insurance claim

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forms. NSQIP data are nationally benchmarked to be comparable across various hospitals. The data are collected prospectively, validated, and submitted from multiple states across hundreds of hospitals, and each hospital submission is guided by randomization process to minimize sampling bias. There are 136 variables collected prospectively. The data include demographic information, preoperative risk factors, intraoperative variables, and postoperative events for 30 days after their operation. All reported data were validated by vigorous quality checks by NSQIP. The full list of information collected is available at NSQIP (http://site.acsnsqip.org/wp-content/uploads/2012/03/2010-User-Guide_FINAL.pdf). The NSQIP participant use data files included 152,490 subjects in 2005 and 2006, 211,407 subjects in 2007, 271,368 subjects in 2008, 336,190 subjects in 2009, and 363,431 subjects in 2010.

Study Sample

To define our study cohort, we included patients with the Current Procedural Terminology (CPT) code for either partial or total knee arthroplasty as their principal procedure (CPT codes 27447, 27446, 27445, 27438, 27487, and 27486). There were total of 18,137 entries with the listed CPT codes as the principal procedure. We excluded patients with bilateral knee arthroplasty as defined by a relevant concurrent CPT code since patients undergoing bilateral knee arthroplasty have been reported to have a significantly increased risks of perioperative complications.[16] We also excluded patients who received an anesthesia type other than GA, spinal, or epidural. Next, we excluded patients who had preexisting infections or infectious conditions as documented in the NSQIP database including pneumonia, systemic inflammatory response syndrome, sepsis, septic shock, or contaminated/infected/dirty wound classification. Last, we excluded ventilator-dependent patients.

Exposure Variable

The Participant Use Data File coded anesthesia type into the following categories: GA, epidural, spinal, regional, monitored anesthesia care, local, other, none, or unknown. In cases where GA was used concurrently with another type of anesthesia, patients were coded as receiving GA. For the present study, we grouped patients receiving spinal and epidural anesthesia together in a single category as NA. All patients undergoing knee arthroplasty with anesthesia type other than GA, epidural, or spinal anesthesia were excluded from the study, including patients with primary anesthesia type as regional/peripheral nerve block.

Study Variables

The NSQIP dataset contains demographic information (age, gender, height, weight, and race), type of anesthesia, ASA physical status classification, level of functional dependence before surgery in activities of daily living (independent, partially dependent, or totally dependent), wound classification (clean, clean/contaminated, contaminated, or dirty/infected), and comorbidities. For this study, we created variables corresponding to the following comorbidities: severe chronic obstructive pulmonary disease, congestive heart failure, coronary artery disease (defined as history of myocardial infarction, prior percutaneous coronary intervention, previous cardiac surgery, or history of angina in 1 month before surgery), peripheral vascular disease (defined as history of revascularization/amputation for peripheral vascular disease, or rest pain/gangrene), hypertension requiring medications, diabetes mellitus with or without insulin treatment, end-stage liver disease (defined as presence of ascites and esophageal varices), kidney failure (defined as acute renal failure or currently on dialysis), central nervous system (CNS) disease (defined as impaired sensorium, coma >24 hours, history of transient ischemic attack, cerebrovascular accident/stroke with or without neurological deficit, or tumor involving CNS), spinal cord injury (defined as hemiplegia, paraplegia, or quadriplegia), and active malignancy (defined as disseminated cancer, chemotherapy, or radiotherapy for malignancy).

Outcome Variables

We obtained data on 8 postoperative infectious complications. These included superficial wound infection, deep incisional wound infection, organ space surgical site infection, surgical wound disruption, pneumonia, urinary tract infection, sepsis, and septic shock. Details on variable definitions are listed in Table 1 as defined in NSQIP user guide. In brief, all 8 variables were defined either as diagnosed by surgeon or attending physician, or on the basis of predefined clinical and laboratory criteria. We additionally defined a ninth composite outcome of any systemic infectious complications as the occurrence of any infection within 30 days, including all 8 infection-related variables as listed above.

Statistical Analysis

All data analysis was executed in STATA 12.1 statistical software (StataCorp LP, College Station, TX). Initial analyses used Fisher exact test and χ^2 test for categorical data, and Student t test and Wilcoxon test for interval data, with statistic significance as $P < 0.05$. Our main focus was comparing infectious outcomes between NA and GA groups. For complications for which we observed statistically significant associations with anesthesia type, we next developed a multivariable logistic regression model to control for potential confounding by preexisting comorbidities and other patient factors. The independent variables included types of anesthesia, age, gender, race, body mass index (BMI), and preexisting comorbidities listed above. In addition, we included surgical time and year of surgery as independent variables. The surgical time was defined as total operation time in minutes. The surgical time was first log transformed to adjust the skewed distribution. We also included perioperative bleeding and transfusion as an independent variable. The perioperative bleeding and transfusion was defined as positive with either received transfusion of packed red blood cells or whole blood from 72 hours before surgery to 72 hours postoperatively. The modeling process used backward elimination with a threshold of $P < 0.2$ for variable inclusion. Adjusted odds ratio (OR), 95% confidence interval (CI), and P values were reported. We elected to use the word "risk" in place of "odds" in the Discussion section, given the low underlying incidence rates. The adequacy of modeling was assessed by C-statistics. We used heteroskedasticity robust standard errors in all regression models.[17]

We also conducted regression analysis based on propensity score to compensate for influence from nonrandom

Table 1. American College of Surgeons National Surgical Quality Improvement Program (NSQIP) Definition of 8 Major Infection Outcome Variables Adapted from NSQIP User Guide

Variable label	Variable definition
Superficial surgical site infection	Infection occurs within 30 d after the operation, and the infection involves only skin or subcutaneous tissue of the incision and at least one of the following: purulent drainage, organisms isolated, or at least one of the following: pain or tenderness, localized swelling, redness, or heat.
Deep incisional surgical site infection	Infection occurs within 30 d after the operation, and the infection appears to be related to the operation and involves deep soft tissues of the incision and at least one of the following: purulent drainage, spontaneously dehisces or is deliberately opened by a surgeon, an abscess, or other evidence of infection.
Organ space surgical site infection	Infection occurs within 30 d after the operation, and the infection appears to be related to the operation and involves any part of the anatomy (e.g., organs or spaces), other than the incision, which was opened or manipulated during an operation, and at least one of the following: purulent drainage from a drain, organisms isolated, or abscess or other evidence of infection involving the organ/space.
Surgical wound disruption	Separation of the layers of a surgical wound, which may be partial or complete, with disruption of the fascia within 30 d of the operation.
Pneumonia	Meet 1 of the following 2 criteria within 30 d of the operation: Criterion 1: Rales or dullness to percussion on physical examination of chest AND any of the following: new onset of purulent sputum, organism isolated from blood culture, tracheal, or bronchial specimen. Criterion 2: Chest radiography evidence AND any of the following: new onset of purulent sputum, organism isolated (from blood culture, tracheal, bronchial specimen, or in respiratory secretions), antibody titer increase for pathogen, or histopathologic evidence of pneumonia.
Urinary tract infection	Meet 1 of the following 2 criteria within 30 d of the operation: 1. One of the following: fever, urgency, frequency, dysuria, suprapubic tenderness, AND positive urine culture. 2. Two of the following: fever, urgency, frequency, dysuria, suprapubic tenderness, AND any of the following: dipstick test positive for leukocyte esterase and/or nitrate, pyuria, organisms seen on Gram stain of unspun urine.
Sepsis	Report this variable if the patient has 2 of the following clinical signs and symptoms: temperature >38°C or <36°C, HR >90 bpm, RR >20/min or $Paco_2$ <32 mm Hg, WBC >12,000 (or <4000) cells/mm^3, >10% immature forms, anion gap acidosis, AND one of the following: positive blood culture, or clinical documentation of purulence or positive culture.
Septic shock	Clinical signs and symptoms of SIRS or sepsis AND documented organ and/or circulatory dysfunction. Examples of organ dysfunction include: oliguria, acute alteration in mental status, and acute respiratory distress. Examples of circulatory dysfunction include hypotension, requirement of inotropic, or vasopressor agents.

Adapted from http://site.acsnsqip.org/wp-content/uploads/2012/03/2010-User-Guide_FINAL.pdf.
SIRS = systemic inflammatory response syndrome; HR = heart rate; RR = respiratory rate; WBC = white blood cell.

selection of GA versus NA as previously described.[18,19] Propensity score analysis is popular in analyzing low incident events to control for confounders.[20] Propensity scores were calculated to reflect the probability of receiving NA with logistic regression model that included all study variables as listed above (including age, gender, BMI, race, ASA status, level of functional status, and all comorbidities). The patient population was then stratified into 5 quintiles based on the propensity scores. For each significant finding from the multivariable regression analysis, we conducted logistic regression analysis with the dependent variable, type of anesthesia, and propensity score quintiles to validate the significance.

RESULTS

We identified 18,137 patients who underwent either partial or total knee arthroplasty. We excluded 222 (1.22%) entries with bilateral knee arthroplasty, 1095 patients with types of anesthesia other than NA or GA, including regional anesthesia/peripheral nerve block ($n = 955$), monitored anesthesia care ($n = 77$), other ($n = 45$), local ($n = 1$), or unknown ($n = 17$) anesthesia type. We further eliminated patients with preexisting conditions, including current pneumonia ($n = 5$), ventilator dependency ($n = 3$), sepsis/septic shock/systemic inflammatory response syndrome ($n = 88$), and dirty/infected/contaminated wound ($n = 169$). In the remaining cohort of 16,555 patients, 9167 patients received GA, 6875 patients received spinal anesthesia, and 513 patients received epidural anesthesia.

There were 7388 (44.63%) subjects in the NA group and 9167 (55.37%) subjects in the GA group (Table 2). The NA group was older than the GA group. The gender distributions within each group were similar with more female patients than males. The NA group had lower BMI on average compared with the GA group. Patients were predominantly Caucasian in both groups.

There were several significant differences among the prevalence of preexisting comorbidities and physical status between the GA and NA groups (Table 3). The GA group had more frequent preoperative renal failure (0.35% vs 0.16%), bleeding disorders (3.41% vs 1.88%), and prior surgery within 30 days preoperatively (0.54% vs 0.22%) compared with the NA group. The NA group had more patients with partially dependent or completely dependent function status in activities of daily living before surgery (4.45% vs 3.69%) and more patients with hypertension requiring medication (70.36% vs 68.19%) than the GA group.

The overall mortality was 0.24% and 0.15% among NA and GA subjects, respectively ($P = 0.214$). The NA group had statistically significant lower incidences of pneumonia (0.24% vs 0.45%, $P = 0.035$) and composite systemic infection (2.95% vs 3.73%, $P = 0.006$) (Table 4).

Logistic regression analysis with risk adjustment from preexisting comorbidities demonstrated that NA was associated with lower odds of pneumonia occurrence (OR = 0.51 [95% CI, 0.29–0.90]) (Table 5). The regression model for pneumonia risk included anesthesia type, age, gender, race, CNS disease, diabetes, dyspnea, and functional health

Table 2. Patient Demographic Information Summary by Anesthesia Type

	General anesthesia	Neuraxial anesthesia	*P*-value
Total subjects, *N* (%)	9167 (55.37)	7388 (44.63)	
Age, mean ± SD	66.41 ± 10.61	67.51 ± 10.17	<0.0001
Gender, *N* (%)			
Male	3262 (35.69)	2730 (37.00)	0.084
Female	5878 (64.31)	4649 (63.00)	
Unknown	27	9	
Body mass index, mean ± SD	32.83 ± 7.97	32.36 ± 7.29	0.0001
Race, *N* (%)			
Caucasian	7311 (82.82)	5691 (82.85)	<0.001
African American	614 (6.96)	572 (8.33)	
Hispanic	727 (8.24)	427 (6.22)	
Others	176 (1.99)	179 (2.61)	
Unknown	339	519	

All values were reported as mean ± SD or number (percentage). The unit of measure for BMI is kilogram per square meter. "Other race" included patients listed as Native Hawaiian or Pacific Islander, Asian or Pacific Islander, Asian, and American Indian, or Alaska Native in the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database.

status before surgery. The C-statistic of the regression model was 0.71. The pneumonia risk was further evaluated in logistic regression analysis with propensity score analysis, and results were comparable (95% CI, 0.29–0.92, Table 6). Logistic regression analysis of composite systemic infection also indicated that NA was associated with lower odds for any systemic infection than GA (OR = 0.77 [95% CI, 0.64–0.92]) (Table 7). The independent variables included in this model were anesthesia type, age, race, BMI, steroid use for chronic condition, diabetes, dyspnea, functional health status before surgery, ASA physical status classification, and surgical time. The C-statistic of the regression model was 0.64. Similarly, we conducted logistic regression analysis on composite systemic infection risk with propensity quintiles; the results showed the same significance (95% CI, 0.64–0.92, Table 8).

DISCUSSION

Our study using a large prospectively collected database of 16,555 knee arthroplasty patients showed that NA was associated with lower incidence of pneumonia and composite systemic infection relative to GA within 30 days postoperatively. The data suggested a 49% reduction in pneumonia risk ($P = 0.021$) and 23% reduction of any systemic infectious complication risk ($P = 0.004$).

Our work adds to the literature on the comparative effectiveness of differing anesthesia types for preventing postoperative infectious complications. Rodgers et al.[11] conducted a meta-analysis on postoperative infectious complications across a range of surgical procedures. Their analysis indicated a decreased risk of pneumonia in NA patients, with an OR of 0.61 (95% CI, 0.48–0.76) based on 28 clinical trials. A similar meta-analysis study by Nishimori et al.[12] also focused on pneumonia risk after abdominal aortic surgery. Their analysis included 7 studies and demonstrated a combined OR of 0.64 (95% CI, 0.38–1.05) in favor of epidural anesthesia without statistical significance. Wu et al.[15] conducted a retrospective study of Medicare patients and found the use of epidural analgesia may contribute to an

Table 3. Prevalence of Preexisting Comorbidities

	General anesthesia		Neuraxial anesthesia		
Comorbidity	***N***	**%**	***N***	**%**	***P*-value**
ASA physical status classification					
IV—life threat	179	1.96	128	1.74	0.291
III—severe disturbance	4449	48.67	3543	48.03	
II—mild disturbance	4340	47.48	3583	48.58	
I—no disturbance	173	1.89	122	1.65	
Functional health status before surgery					
Dependent	6	0.07	11	0.15	0.020
Partially dependent	332	3.62	318	4.30	
Independent	8828	96.31	7059	95.55	
Congestive heart failure in 30 d before surgery	17	0.19	7	0.09	0.152
Coronary artery disease	1011	11.03	776	10.51	0.290
Peripheral vascular disease	61	0.67	48	0.65	0.923
HTN requiring medication	6251	68.19	5198	70.36	0.003
Dyspnea					
At rest	26	0.28	24	0.32	0.350
Moderate exertion	872	9.51	657	8.89	
History of severe COPD	338	3.69	252	3.41	0.354
End-stage liver disease	5	0.05	1	0.01	0.235
Renal failure	32	0.35	12	0.16	0.022
Diabetes mellitus with oral drugs or insulin					
Insulin	409	4.46	291	3.94	0.164
Oral/noninsulin	1267	13.82	1064	14.40	
None	7491	81.72	6033	81.66	
Central nervous system disease	535	5.84	417	5.65	0.615
Spinal cord injury	42	0.46	23	0.31	0.169
Disseminated cancer, chemotherapy/radiotherapy	37	0.40	23	0.31	0.364
Bleeding disorders	313	3.41	139	1.88	<0.001
Prior operation within 30 d	49	0.54	16	0.22	0.001

HTN = hypertension; COPD = chronic obstructive pulmonary disease.

Table 4. Incidences of 30-Day Postoperative Complications

	General anesthesia		Neuraxial anesthesia		
Variable label	***N***	**%**	***N***	**%**	***P*-value**
Superficial surgical wound infection	79	0.86	55	0.74	0.433
Deep incisional wound infection	20	0.22	15	0.20	0.867
Organ/space surgical site infection	20	0.22	14	0.19	0.733
Surgical wound disruption	24	0.26	21	0.28	0.881
Pneumonia occurrences	41	0.45	18	0.24	0.035
Urinary tract infection occurrences	154	1.68	97	1.31	0.055
Sepsis occurrences	47	0.51	24	0.32	0.073
Septic shock occurrences	11	0.12	8	0.11	1
Composite systemic infection	342	3.73	218	2.95	0.006

increase in 30 days pneumonia risk with OR of 1.91 (95% CI, 1.09–3.34). It is noteworthy that Wu et al.[15] included various surgical procedures, such as segmental excision of the lung, complete pneumonectomy, partial excision of large intestine, anastomosis of the esophagus, total knee replacement and revision, abdominal hysterectomy, pancreaticoduodenectomy, nephrectomy, cystectomy, hepatotomy/lobectomy of the liver, gastrectomy, and radical retropubic prostatectomy. The heterogeneous nature of the surgical procedures and the inclusion of both thoracic and lumbar epidural anesthesia among these procedures might partially explain the differences between the results of the current study and Wu et al.[15]

There have been very few studies examining the association of anesthesia type with postoperative infectious complications among patients undergoing orthopedic procedures.[13,14,21] A meta-analysis by Parker et al.[13] of 9 clinical trials with 1125 patients did not show any reduction in pneumonia risk by NA in adult hip fracture surgery. The differences between our findings and those of Parker et al.[13] may be explained in part by clinical differences between hip fracture patients and patients undergoing elective hip or knee arthroplasty. Another meta-analysis on total hip and knee replacement surgery had insufficient power with respect to infection with a combined sample size of 204 subjects.[14] Chang et al.[21] conducted a retrospective study of 3081 patients with total hip or knee replacement between 2002 and 2006 and concluded that GA was associated with a greater odds of surgical site infection compared with epidural or spinal anesthesia. We examined 4 surgical site–related infection variables, including superficial surgical site infection, deep incisional surgical site infection, organ space surgical site infection, and surgical wound disruption. However, none differed significantly between GA and NA. Notably, the overall incidence of surgical site infections was lower in our study than in the study of Chang et al.[21] It is unclear whether this was due to the fact that our study only included knee replacement, or that our patients were from more recent years than included in this earlier work. Our study suggested that spinal or epidural anesthesia decreased pneumonia risk among knee arthroplasty patients by about 49%. This observation could be attributed to less systemic immune disturbance in the NA group compared with the GA group. In addition, the potential absence of airway instrumentation and mechanical ventilation in the NA group might also have been an important confounder as GA is related to increased risks of airway trauma and atelectasis.

We acknowledge that the retrospective observational nature of this study is a limitation. Future prospective randomized studies are needed to confirm our findings. Another limitation of the current study lies in the coding system of anesthesia type. In a case of concurrent use of GA with NA, patients were coded as receiving GA. There was no detail information on GA, such as with endotracheal tube, laryngeal mask airway, or others, which could have contributed to the differences in outcome complications. This study is also limited by the number of variables listed in the NSQIP database. There are other important risk factors that might be important for infectious risk, such as hypothermia, level of immediate postoperative mental status, and etc. However, there is no information in the NSQIP database. The current study included patients from 2005 to 2010, during that time prophylactic antibiotic regimes might have changed, which could have affected the infectious outcomes. However, there is no such information in the NSQIP database on prophylactic antibiotic regimes. The hospital identification and surgeon identification information were also removed

Table 5. Multivariable Regression Analysis, Odds Ratios, and 95% CI with Pneumonia Occurrence as Dependent Variable

Independent variable	Odds ratio (95% CI)	*P*-value
Anesthesia type	0.51 (0.29–0.90)	0.021
Age	1.66 (1.31–2.11)	<0.001
Gender	0.53 (0.31–0.89)	0.016
Race—other	5.39 (2.14–13.57)	<0.001
Central nervous system disease	1.84 (0.89–3.82)	0.099
Dyspnea—moderate exertion/at rest	1.98 (0.99–3.95)	0.052
Diabetes—insulin dependent	2.58 (1.14–5.85)	0.023
Functional health status previous to surgery—partially dependent/dependent	2.00 (0.80–4.99)	0.139

Odds ratio and 95% confidence interval (CI) were reported to 2 digits, while *P*-values were reported to 3 digits. We also analyzed potential interactions between anesthesia type and all other independent variables via univariable regression analysis, and no significant interactions were identified (all $P > 0.13$).

Table 6. Regression Analysis with Propensity Score (PS) on Pneumonia

Independent variable	Odds ratio (95% CI)	*P*-value
Anesthesia type	0.52 (0.29–0.92)	0.025
PS_quintile_2	1.38 (0.48–3.98)	0.552
PS_quintile_3	1.75 (0.64–4.83)	0.278
PS_quintile_4	2.46 (0.94–6.42)	0.065
PS_quintile_5	3.28 (1.30–8.28)	0.012

CI = confidence interval.

Table 7. Multivariable Regression Analysis, Odds Ratios, and 95% CI with Composite Systemic Infection as Dependent Variable

Independent variable	Odds ratio (95% CI)	*P*-value
Anesthesia type	0.77 (0.64–0.92)	0.004
Age	1.23 (1.12–1.35)	<0.001
Race–Hispanic	0.70 (0.48–1.03)	0.072
Race–Other	1.82 (1.13–2.95)	0.014
Body mass index	1.02 (1.01–1.03)	0.001
Steroid use for chronic condition	1.71 (1.11–2.63)	0.015
Diabetes—insulin dependent	1.54 (1.11–2.15)	0.011
Dyspnea—moderate exertion/ at rest	1.22 (0.94–1.58)	0.131
Functional health status previous to surgery—partially dependent/dependent	1.35 (0.94–1.95)	0.106
ASA physical status classification: III—severe disturbance	1.52 (1.25–1.85)	<0.001
ASA physical status classification: IV—life threatening concurrent disease	1.80 (1.09–2.99)	0.022
Operation year	0.92 (0.84–1.01)	0.065
Surgical time (log[min])	1.94 (1.52–2.48)	<0.001

Odds ratio and 95% confidence interval (CI) were reported to 2 digits, while *P*-values were reported to 3 digits. Odds ratio for surgical time is per unit of the transformed time (log[minutes]).

Table 8. Regression Analysis with Propensity Score (PS) on Composite Systemic Infection

Independent variable	Odds ratio (95% CI)	*P*-value
Anesthesia type	0.77 (0.64–0.92)	0.004
PS_quintile_2	0.73 (0.55–0.97)	0.031
PS_quintile_3	0.82 (0.62–1.08)	0.150
PS_quintile_4	0.88 (0.67–1.15)	0.353
PS_quintile_5	1.08 (0.84–1.40)	0.549

CI = confidence interval.

by NSQIP to comply with the participation agreement between NSQIP and participating sites. Furthermore, information on postoperative analgesia techniques was missing from the NSQIP dataset, which may have affected the surgical outcomes.

Nonetheless, our study suggests that NA may offer advantages over GA for knee arthroplasty by reducing the likelihood of selected infectious complications, especially pneumonia. Although this study confirmed our hypothesis clinically, it does not provide explanations regarding the mechanisms underlying the associations we observed. Studies on immune response to various anesthesia techniques have been inconclusive due to the heterogeneity among subjects.

In conclusion, our study demonstrated that NA was associated with a lower incidence of both pneumonia and any systemic infectious complication within 30 days of surgery compared with GA in patients undergoing knee arthroplasty. While NA is advantageous from a 30-day postoperative infection aspect, the underlying mechanism is still unknown. As such, further prospective investigations are needed to confirm our findings.

DISCLOSURES

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Contribution: This author helped design and conduct the study, data analysis, and prepare the manuscript.
Attestation: Jiabin Liu approved the final manuscript. Jiabin Liu attests to the integrity of the original data and the analysis reported in this manuscript and is the archival author.
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