ANESTHESIOLOGY

Association of Patient Race and Hospital with Utilization of Regional Anesthesia for Treatment of Postoperative Pain in Total Knee Arthroplasty: A Retrospective Analysis Using Medicare Claims

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ABSTRACT

Background: Regional anesthesia for total knee arthroplasty has been deemed high priority by national and international societies, and its use can serve as a measure of healthcare equity. The association between utilization of regional anesthesia for postoperative pain and (1) race and (2) hospital in patients undergoing total knee arthroplasty was estimated. The hypothesis was that Black patients would be less likely than White patients to receive regional anesthesia, and that variability in regional anesthesia would more likely be attributable to the hospital where surgery occurred than race.

Methods: This study used Medicare fee-for-service claims for patients aged 65 yr or older who underwent primary total knee arthroplasty between January 1, 2011, and December 31, 2016. The primary outcome was administration of regional anesthesia for postoperative pain, defined as any peripheral (femoral, lumbar plexus, or other) or neuraxial (spinal or epidural) block. The primary exposure was self-reported race (Black, White, or Other). Clinical significance was defined as a relative difference of 10% in regional anesthesia administration.

Results: Data from 733,406 cases across 2,507 hospitals were analyzed: 90.7% of patients were identified as White, 4.7% as Black, and 4.6% as Other. Median hospital-level prevalence of use of regional anesthesia was 51% (interquartile range, 18 to 79%). Black patients did not have a statistically different probability of receiving a regional anesthetic compared to White patients (adjusted estimates: Black, 53.3% [95% CI, 52.5 to 54.1%]; White, 52.7% [95% CI, 52.4 to 54.1%]; $P = 0.132$). Findings were robust to alternate specifications of the exposure and outcome. Analysis of variance revealed that 42.0% of the variation in block administration was attributable to hospital, compared to less than 0.01% to race, after adjusting for other patient-level confounders.

Conclusions: Race was not associated with administration of regional anesthesia in Medicare patients undergoing primary total knee arthroplasty. Variation in the use of regional anesthesia was primarily associated with the hospital where surgery occurred.

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Regional analgesia for management of postoperative pain after total knee arthroplasty is recommended by numerous relevant societies
- Black patients undergoing total knee arthroplasty have worse outcomes compared to White patients
- Previous analyses of postoperative analgesia management among commercially insured patients demonstrate lower frequency of peripheral nerve blocks among Black patients compared to White patients

What This Article Tells Us That Is New

- Among 733,406 primary total knee arthroplasty surgeries between January 1, 2011, and December 31, 2016, in the Medicare database, 90.7% of patients identified as White, 4.7% as Black, and 4.6% as Other
- Black patients did not have a statistically different probability of receiving a regional anesthetic compared to White patients (adjusted estimates: Black, 53.3% [95% CI, 52.5 to 54.1%]; White, 52.7% [95% CI, 52.4 to 54.1%]; $P = 0.132$)
- After adjustment for other patient-level confounders, 42.0% of the variation in block administration was attributable to the hospital, compared to less than 0.01% to race
- Race was not associated with administration of regional anesthesia in Medicare patients undergoing primary total knee arthroplasty

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Regional anesthesia for total knee arthroplasty, one of the most common surgeries in the United States,[1] has been deemed high priority *via* national performance measures[2] and strongly recommended by international consensus.[3] The use of regional anesthesia in total knee arthroplasty is associated with improved postoperative analgesia and decreased opioid use,[4] along with decreased risk of serious complications including end-organ damage, blood loss, and surgical site infection.[3] Given that administration of regional anesthesia for management of postoperative pain in total knee arthroplasty is well substantiated, its use can also serve as an important measure of potential anesthesia-related healthcare disparities, as called for by leaders in the field.[5]

Specifically, evaluating whether Black patients receive lower-quality analgesic care when undergoing total knee arthroplasty is important given other known disparities experienced by this surgical population. Black patients undergo total knee arthroplasty at lower rates than White patients,[6,7] report worse functional outcomes postoperatively,[8] and are more likely to experience major postoperative adverse outcomes including death.[9] While one study found that Black patients who underwent total joint arthroplasty were less likely to receive regional anesthesia,[10] that analysis used a database with an unvalidated self-reported race and ethnicity variable[11] and reported lower regional anesthesia utilization compared to other studies focused on the same time period.[12]

Further, hospital care for Black patients is disproportionately concentrated in a small percentage of hospitals in the United States that have historically reported lower scores on performance metrics.[13,14] Our previous work using a database of commercially insured patients found that hospitals with larger proportions of patients identified as Black or from other historically marginalized backgrounds were less likely to provide regional anesthesia to patients undergoing total knee arthroplasty.[15] However, that work did not include most Medicare patients, who account for the majority of total knee arthroplasties performed in the United States.[16] Another study using a convenience sample of nationwide hospital discharges also found that some hospital characteristics—such as annual volume of joint arthroplasty surgeries—were associated with regional anesthesia utilization, but that work did not cluster its findings by the hospital itself.[17] Therefore, further delineating the relationship between hospital and regional anesthesia utilization using a more representative, national sample may help guide interventions aimed at improving health equity.

Based on these considerations, we used a large national claims data set representing 100% of Medicare fee-for-service enrollees to first assess whether disparities existed in the provision of regional anesthesia for postoperative analgesia in Black compared to White patients who underwent primary total knee arthroplasty. As an exploratory analysis, we also evaluated this relationship for patients identified as non-White and non-Black. Second, we assessed the extent to which the hospital where surgery occurred drove variation in use of regional anesthesia. We hypothesized that (1) Black patients would be less likely to receive regional anesthetic techniques than White patients and (2) variability in regional anesthesia utilization would more likely be attributable to hospital than race.

Materials and Methods

Data

We used healthcare claims for 100% of Medicare fee-for-service patients who underwent major surgery between January 1, 2011, and December 31, 2016, using the Medicare Inpatient, Outpatient, Medicare Provider Analysis and Review, Carrier, and Master Beneficiary Summary Files. These data included information about each patient's demographic characteristics (*e.g.*, age, sex, and race), healthcare utilization including procedures and prescription medication fills, and diagnosis codes (International Classification of Diseases, Ninth or Tenth Revision). This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline for cohort studies[18] and received approval of waiver of consent from the Stanford University Institutional Review Board. A prespecified analysis plan defining the study sample, set of associated variables, and data analysis plan was written and recorded in the investigators' files before analyses were performed.

Sample

We constructed an initial sample of patients who underwent unilateral primary total knee arthroplasty between January 1, 2011, and December 31, 2016, identified using Current Procedural Terminology (CPT) code 27447 in the Medicare carrier file. We restricted the sample to patients with a continuous year of enrollment in Medicare Parts A, B, and D before their surgery. This initial sample had a total of 846,260 surgeries across 740,538 patients.

Next, we implemented the following stepwise exclusion criteria: (1) surgeries with no corresponding hospital claim or demographic information, which indicated the surgery did not occur in an inpatient facility (n = 4,903); (2) surgeries from hospitals that performed less than 50 total knee arthroplasty surgeries over the entire study timeframe (n = 21,951 surgeries, excluding 1,236 out of 3,743 hospitals) given our planned adjustment for hospital fixed effects as described in "Covariates";; and (3) patients younger than 65 yr old (n = 86,000), given that patients under age 65 would have qualified for Medicare due to specific medical conditions (*e.g.*, end-stage renal disease) and were likely systematically different than those above the enrollment age threshold. The final data set included 733,406 surgeries across 644,117 patients and 2,507 hospitals (see supplemental digital fig. 1, https://links.lww.com/ALN/D362, for flowchart depicting sample construction).

Exposure

Our primary exposure of interest was self-reported race, which was obtained from the Medicare enrollment database. The self-reported race variable is derived from Medicare beneficiaries' Social Security Administration data, which is itself derived from individuals' applications for a Social Security number. Before 1980, the Social Security Administration only offered three race categories: White, Black, and Other. After 1980, this categorization was expanded to offer six categories: non-Hispanic White; non-Hispanic Black; Asian, Asian American, or Pacific Islander; Hispanic; North American Indian or Alaska Native; and other. Given these changes, the race/ethnicity variable in Medicare claims data are only valid for the White and Black categories, which generally have sensitivities and specificities above 90%.[19] We therefore focused our analysis on patients who self-reported race as White or Black, and we collapsed the small number of patients in alternate categories (1.1% Hispanic, 1.4% Asian, 0.4% Native American, 0.7% unknown, and 1.0% other) into our category of Other for exploratory analysis.

The Medicare enrollment database race variable has been compared to a second race variable created by researchers at Research Triangle Institute, which improves the accuracy of identifying Hispanic and Asian/Pacific Islander populations using imputed name and geographic indicators.[20] Given that our analysis focused on patients who identified as Black or White, we used the enrollment database race variable for our primary analysis, but we also conducted two *post hoc* sensitivity analyses using the Research Triangle Institute race variable.

Outcomes

Our primary outcome was a composite representing whether the patient received a regional anesthetic—defined as any peripheral nerve or neuraxial block—for the treatment of postsurgical pain. We identified patients who received a block by identifying whether they had any of the following CPT codes submitted for the same date of service as the date of surgery: 64447/64448 (femoral nerve single-injection block or catheter), 64449 (lumbar plexus catheter), 64450 (other peripheral nerve block), 62318 (spinal block), and 62319 (epidural block). Because separate claims are only submitted for blocks performed for the purpose of postoperative analgesia, this outcome did not include any blocks (*e.g.*, neuraxial blocks) that were administered solely as the intraoperative anesthetic; thus, the outcome variable represented regional anesthesia that the primary anesthesiologist intended as part of the postoperative analgesic strategy.

Covariates

To adjust for potential confounding, we included the following covariates: (1) age; (2) sex; (3) Elixhauser comorbidities,[21] with each variable set to 1 if the patient had at least one claim with a relevant International Classification of Diseases code in the 365 days before their surgery or set to 0 otherwise; (4) preoperative opioid use, included as two variables representing average daily morphine milligram equivalents[22] in the (a) 7 to 90 days before surgery or (b) in the 91 to 365 days before surgery; and (5) preoperative antiplatelet or anticoagulant use, included as two binary variables set to 1 for any (a) antiplatelet or (b) anticoagulant medication fills in the 6 months before date of surgery and 0 otherwise. We chose these covariates based on clinical judgment as well as other studies on variability in orthopedic surgery that have used similar definitions for comorbidities and antiplatelet/anticoagulant use.[23] We further included fixed effects for (1) year, to account for potential trends in use of regional anesthesia over time, and (2) hospital, to allow for adjustment for unmeasured factors unique to a given hospital (*i.e.*, baseline tendency for anesthesiologists at that hospital to administer blocks). Inclusion of these fixed effects thereby allowed for comparison of block utilization by race within, rather than across, hospital and year.

Statistical Analysis

As a first step, we compared demographic variables and unadjusted regional anesthesia utilization in Black and Other patients compared to White patients. We used two-sided *t* tests to assess for statistically significant differences in continuous variables and chi-squared tests to assess for differences in categorical variables. Because of the large sample size, even small differences between groups may be statistically significant; therefore, we also used Hedges' g[24] to estimate the magnitude of the standardized differences between groups. Hedges' g is the difference between the means of two groups divided by the population standardized difference, small differences associated with values of less than 0.2, moderate differences with values 0.2 to 0.5, and large differences with values greater than 0.5.[25]

To test our first hypothesis, we estimated the association between race and receipt of regional anesthesia using a multivariable logistic regression model. Our dependent variable was whether the patient received a regional anesthetic or not, and the independent variable was race, with White patients set as the reference group. This model further included the covariates listed in "Covariates," including year and hospital as fixed effects. We calculated robust standard errors grouped at the patient level, which accounted for patients in our cohort who underwent more than one primary total knee arthroplasty during the study period (*i.e.*, those who had surgery on each knee at different times). We converted odds ratios from our logistic regression models to predicted probabilities for ease of interpretation, and we *a priori* defined a clinically significant disparity as a relative difference of at least 10% in block utilization across groups.[26]

To test our second hypothesis, we conducted an analysis of variance using all of the variables included in the above model and further calculated the eta-squared for each of these variables to quantify the magnitude of each variable's effect on the outcome. The eta-squared represented the proportion of variance in use of regional anesthesia that could be attributed to that specific variable and allowed for comparisons of the variability accounted for by patient-level characteristics relative to other independent variables (*i.e.*, race compared to hospital). All analyses were performed using STATA 17.0 (StataCorp LLC, USA).

Sensitivity Analyses

We conducted prespecified sensitivity analyses estimating the association between race and receipt of (1) only peripheral nerve blocks (*e.g.*, femoral, lumbar plexus, or other) and (2) only femoral nerve blocks, using all covariates included in the multivariable logistic regression model described. Further, given concerns about validity of the race variable for patients grouped into the Other race category, we assessed for robustness of our findings by repeating the analyses but instead (1) assigning all patients in the Other category to White, (2) assigning all patients in the Other category to Black, and (3) randomly assigning patients in the Other category to White or Black while maintaining the study population's proportionate distribution of White and Black patients. In response to reviewer feedback, we also added several *post hoc* sensitivity analyses. First, we repeated the analysis using the Medicare Research Triangle Institute race variable instead of the enrollment database variable (as described), using the same categories as our primary analysis and also disaggregating Other into Hispanic, Asian and Pacific Islander, and Other. Second, we restricted the analysis to hospital-year combinations with more than 50 total knee arthroplasty surgeries, thus excluding any hospitals that had low surgical volume in a given year.

Exploratory Analyses

As noted, our analyses evaluating regional anesthesia utilization for patients categorized in the Other race category were exploratory, given the history of the race/ethnicity variable in this data set. In response to reviewer feedback, we also conducted an additional exploratory analysis identifying utilization of regional anesthesia utilization stratified by hospital characteristics. We linked our data set to the publicly available Medicare Provider of Services file and then categorized hospitals by surrounding population density (urban *vs.* rural), number of beds (fewer than 100, 100 to 400, and more than 400), U.S. Census Bureau region (West, Midwest, South, and Northeast), hospital ownership (for-profit, nonprofit, government, and other), and academic status identified by evidence of any allopathic residency program (teaching *vs.* nonteaching). We then calculated the overall proportion of regional anesthesia utilization for hospitals within each hospital characteristic category, and we assessed for statistically significant differences within category using two-sided *t* tests and standardized differences *via* Hedges' g. We further identified the distribution of regional anesthesia utilization by hospital characteristic and assessed the proportion of Black and White patients within each quartile who received regional anesthesia for postoperative pain.

Results

Our final sample consisted of 733,406 primary total knee arthroplasty surgeries, of which 665,036 (90.7%) were performed on patients who were White, 34,821 (4.7%) on patients who were Black, and 33,549 (4.6%) on patients categorized as Other. Compared to White patients, Black patients were moderately more likely to be female and have diabetes or hypertension (table 1). While statistically significant, the magnitude of these and other differences were small to moderate, with Hedges' g less than or equal to 0.4 for all. Approximately 52% of White and Black patients each received any regional anesthetic, and there was therefore no significant difference in unadjusted probability of block receipt. The median prevalence of block administration by hospital was 51% (interquartile range, 18 to 79%) across 2,507 hospitals.

We found no difference across racial groups that met our *a priori* definition of disparity (*i.e.*, a greater than 10% relative difference in regional anesthesia). Black patients did not have a statistically different likelihood of receiving a regional anesthetic compared to White patients after accounting for demographic variables, comorbidities, year of surgery, and hospital: 53.3% Black (95% CI, 52.5 to 54.1%) *versus* 52.7% White (95% CI, 52.4 to 54.1%; $P = 0.132$) received regional anesthesia. Our exploratory analysis for patients in the Other category also did not find a significantly different likelihood of regional anesthetic administration (52.0%; 95% CI, 51.2 to 52.8%; $P = 0.084$) compared to White patients (table 2). Sensitivity analyses conducted to test for robustness of the outcome, defined as only peripheral blocks or only femoral nerve blocks, replicated these results. Sensitivity analyses testing for robustness of the race variable also generally replicated the magnitude of these results when assigning those in the Other category to White or Black as described under "Materials and Methods" or when disaggregating the Other category further into Hispanic and Asian/Pacific Islander (see supplemental digital table 1, https://links.lww.com/ALN/D363, and supplemental digital table 2, https://links.lww.com/ALN/D364).

Analysis of variance found that systemic factors explained much of the variation in use of regional anesthetic techniques. Hospital and year accounted for 42.0% and 0.1% of variation in the use of regional anesthesia, respectively,

Table 1. Characteristics of the Study Population, by Race

	White (N = 665,036, 90.7%)	Relative to White					
		Black (N = 34,821, 4.7%)			Other (N = 33,549, 4.6%)		
Characteristics	**n (SD)**	**n (SD)**	***P***	**Hedges' g**	**n (SD)**	***P***	**Hedges' g**
Demographics							
Age, yr	74.3 (5.7)	73.2 (5.6)	< 0.001	0.18	73.5 (5.8)	< 0.001	0.14
Male sex, %	33.5 (0.5)	19.7 (0.4)	< 0.001	0.29	33.6 (0.5)	0.568	0.00
Medical comorbidities, %							
AIDS/HIV	0.0 (0.0)	0.5 (0.1)	< 0.001	0.18	0.1 (0.0)	< 0.001	0.05
Alcohol abuse	1.0 (0.1)	0.9 (0.1)	0.613	0.00	0.8 (0.1)	0.008	0.01
Blood anemia	2.9 (0.2)	4.1 (0.2)	< 0.001	0.07	3.5 (0.2)	< 0.001	0.04
Cardiac arrhythmias	31.2 (0.5)	29.2 (0.5)	< 0.001	0.04	26.2 (0.4)	< 0.001	0.11
Congestive heart failure	10.3 (0.3)	16.2 (0.4)	< 0.001	0.19	11.1 (0.3)	< 0.001	0.03
Coagulopathy	7.1 (0.3)	7.1 (0.3)	0.956	0.00	8.5 (0.3)	< 0.001	0.05
Chronic pulmonary disease	25.6 (0.4)	30.3 (0.5)	< 0.001	0.11	24.8 (0.4)	0.002	0.02
Deficiency anemia	10.0 (0.3)	15.7 (0.4)	< 0.001	0.18	12.7 (0.3)	< 0.001	0.09
Depression	21.4 (0.4)	15.7 (0.4)	< 0.001	0.14	16.5 (0.4)	< 0.001	0.12
Diabetes, complicated	11.4 (0.3)	23.1 (0.4)	< 0.001	0.36	18.7 (0.4)	< 0.001	0.23
Diabetes, uncomplicated	27.3 (0.5)	44.6 (0.5)	< 0.001	0.39	41.5 (0.5)	< 0.001	0.32
Drug abuse	1.9 (0.1)	3.2 (0.2)	< 0.001	0.10	1.7 (0.1)	0.018	0.01
Fluid and electrolyte disorders	19.9 (0.4)	25.1 (0.4)	< 0.001	0.13	20.5 (0.4)	0.009	0.01
Hypertension, complicated	15.0 (0.4)	26.6 (0.4)	< 0.001	0.32	18.8 (0.4)	<0.001	0.11
Hypertension, uncomplicated	85.9 (0.4)	95.8 (0.2)	< 0.001	0.29	87.9 (0.3)	< 0.001	0.06
Hyperthyroidism	31.3 (0.5)	22.9 (0.4)	< 0.001	0.18	28.0 (0.5)	< 0.001	0.07
Liver disease	4.8 (0.2)	6.1 (0.2)	< 0.001	0.06	7.3 (0.3)	< 0.001	0.12
Obesity	29.9 (0.5)	42.8 (0.5)	< 0.001	0.28	28.4 (0.5)	< 0.001	0.03
Other neurologic disorders	4.7 (0.2)	4.9 (0.2)	0.031	0.01	4.4 (0.2)	0.036	0.01
Paralysis	0.5 (0.1)	0.8 (0.1)	< 0.001	0.05	0.6 (0.1)	< 0.001	0.02
Pulmonary circulation disorder	3.6 (0.2)	4.9 (0.2)	< 0.001	0.07	2.9 (0.2)	< 0.001	0.04
Psychoses	1.8 (0.1)	2.7 (0.2)	< 0.001	0.06	1.5 (0.1)	< 0.001	0.02
Chronic peptic ulcer disease	2.1 (0.1)	2.6 (0.2)	< 0.001	0.03	2.7 (0.2)	0.000	0.05
Peripheral vascular disorders	17.1 (0.4)	21.5 (0.4)	< 0.001	0.12	19.4 (0.4)	0.000	0.06
Renal failure	13.3 (0.3)	21.9 (0.4)	< 0.001	0.25	13.0 (0.3)	0.078	0.01
Rheumatoid arthritis	12.0 (0.3)	15.2 (0.4)	< 0.001	0.10	12.6 (0.3)	0.001	0.02
Valvular disease	18.4 (0.4)	18.5 (0.4)	0.714	0.00	18.5 (0.4)	0.570	0.00
Weight loss	2.9 (0.2)	4.9 (0.2)	< 0.001	0.12	3.5 (0.2)	< 0.001	0.04
Preoperative opioid use (average daily morphine milligram equivalents)							
Long term (91 to 365 days before surgery)	0.6 (2.1)	0.9 (2.4)	< 0.001	0.13	0.5 (1.7)	< 0.001	0.06
Medium term (7 to 90 days before surgery)	0.7 (2.3)	1.0 (2.6)	< 0.001	0.12	0.6 (1.9)	< 0.001	0.06
Preoperative anticoagulant use, %	20.1 (40.1)	14.4 (35.1)	< 0.001	0.14	14.2 (34.9)	< 0.001	0.15
Preoperative antiplatelet use, %	5.7 (23.3)	6.9 (25.4)	< 0.001	0.05	7.0 (25.5)	< 0.001	0.05
Receipt of regional anesthesia, %							
Composite (any) block	52.1 (0.5)	52.3 (0.5)	0.537	0.00	50.5 (0.5)	< 0.001	0.03
Femoral block	46.3 (0.5)	47.7 (0.5)	< 0.001	0.03	45.3 (0.5)	< 0.001	0.02
Spinal	0.0 (0.0)	0.0 (0.0)	0.519	0.00	0.1 (0.0)	0.003	0.02
Epidural	1.2 (0.1)	1.1 (0.1)	0.016	0.01	0.2 (0.1)	< 0.001	0.05
Other peripheral block	6.0 (0.2)	5.3 (0.2)	< 0.001	0.03	5.3 (0.2)	< 0.001	0.03
Lumbar plexus block	0.1 (0.0)	0.1 (0.0)	0.020	0.01	0.0 (0.0)	0.019	0.01

The table presents univariable associations in demographics, selected comorbidities, preoperative analgesic utilization, preoperative anticoagulant and antiplatelet utilization, and primary outcomes, comparing patients identified as Black and other race (respectively) to White patients. We used two-sided *t* tests to assess for statistically significant differences in continuous variables, and chi-squared tests to assess for differences in categorical variables. Further, we calculated Hedges' g standardized differences between groups for each variable. Hedges' g is the difference between the means of two groups divided by the population standardized difference, with small differences associated with values of less than 0.2, moderate differences with values 0.2 to 0.5, and large differences with values greater than 0.5.[25]

AIDS, acquired immunodeficiency syndrome; HIV, human immunodeficiency virus.

while patient-level factors in aggregate accounted for 0.01% of variation (race, less than 0.001%; sex, less than 0.001%; age, 0.003%; all Elixhauser comorbidities, 0.004%; preoperative opioid use, less than 0.001%; preoperative anticoagulant use, 0.001%; and preoperative antiplatelet use, less than 0.001%). Hospital fixed effects therefore explained the vast majority of variation in regional anesthesia usage out of all included independent variables. Figure 1 depicts unadjusted frequency of block administration by hospital plotted against the percentage of White patients treated at that hospital and shows that hospital-level variation does not vary by racial makeup of the patient population.

Table 2. Primary Unadjusted, Adjusted, and Selected Sensitivity Analyses Estimating Probability of Regional Anesthesia Utilization

Analysis	White, % (95% CI)	Compared to White: Black % (95% CI)	Black *P* Value	Other % (95% CI)	Other *P* Value	Notes
Unadjusted analysis	52.1 (52.0–52.2)	52.3 (51.8–52.9)	0.560	50.5 (49.9–51.1)	< 0.001	
Adjusted primary analysis	52.7 (52.4–54.1)	53.3 (52.5–54.1)	0.132	52.0 (51.2–52.8)	0.084	Primary adjusted model accounting for patient age, sex, Elixhauser comorbidities, preoperative opioid, anticoagulant, and antiplatelet utilization, and year and hospital fixed effects
Sensitivity analyses: individual blocks						
Any peripheral block	50.7 (50.4–51.0)	51.5 (50.7–52.3)	0.036*	49.9 (49.1–50.7)	0.060	Adjusted model with outcome respecified as any peripheral block (femoral, lumbar plexus, or other)
Femoral nerve block	43.5 (43.3–43.8)	44.8 (44.0–45.6)	0.002*	42.8 (42.0–43.6)	0.085	Adjusted model with outcome respecified as femoral nerve block only

The table presents our primary unadjusted and adjusted models estimating the association between race and regional anesthesia utilization for postoperative pain, along with selected sensitivity analyses. The primary adjusted model was specified as a multivariable logistic regression that accounted for age, sex, Elixhauser comorbidities, preoperative opioid, anticoagulant, and antiplatelet utilization, and year and hospital fixed effects. Selected sensitivity analyses respecified the outcome as only peripheral blocks and only femoral nerve blocks. Odds ratios were converted to predicted probabilities for ease of interpretation. No comparisons met the prespecified criterion for a clinically significant disparity by race, prespecified as a 10% relative difference. Additional detail and additional sensitivity analyses are presented in supplemental digital table 1 (https://links.lww.com/ALN/D363).

*Significant at the $P < 0.05$ level.

Finally, our exploratory analysis of regional anesthesia utilization by hospital characteristics is presented in table 3. Within hospital characteristics, regional anesthesia utilization in White compared to Black patients was qualitatively similar across quartiles. However, there were differences between hospitals. For example, the proportion of patients in rural hospitals who received regional anesthesia was almost 10% lower than that in urban hospitals (44.6% rural *vs.* 53.3% urban; $P < 0.001$; Hedges' g 0.17, corresponding to a small difference); further, the proportion of patients in Western hospitals who received regional anesthesia was also approximately 10% lower than that in Northeastern hospitals (46.6% West *versus* 56.3% Northeast; $P < 0.001$; Hedges' g 0.20, corresponding to a moderate difference).

Discussion

We did not find evidence of racial disparities in use of regional anesthesia for postoperative pain after primary total knee arthroplasty in our population of Medicare fee-for-service beneficiaries, refuting our primary hypothesis and in contrast to previous literature showing racial disparities in other aspects of care for Black patients undergoing this surgery. We also found that the hospital where a patient received care was the strongest predictor of whether they would receive regional anesthesia, consistent with our secondary hypothesis. The average prevalence of regional anesthesia utilization in our study population was approximately 50%, with a large plurality of patients who did not receive a regional anesthetic despite the substantial evidence base supporting its use. Our findings imply that the hospital where a given patient received care likely determined whether they received evidence-based analgesic care, regardless of race. Our exploratory analysis also identified that patients who underwent surgery in rural hospitals were less likely to receive regional anesthesia for postoperative pain compared to those at urban hospitals and that the overall utilization of regional anesthesia administration was significantly lower in the Western United States compared to the Northeast. These results suggest that total knee arthroplasty care may be influenced by systemic, geographically driven, and socioeconomic factors that affect healthcare access, resources, and quality based on where patients live.

Our null findings on the existence of racial disparities in regional anesthesia for postoperative pain in Black compared to White patients undergoing total knee arthroplasty diverge from other studies that focused mainly on patients who were commercially insured.[15,17] These studies generally had younger study populations that arguably differed in various aspects (*i.e.*, employer-sponsored insurance) from the population involved in the current study. Approximately 5% of our study population was identified as Black, which is slightly lower than reported Black patient populations in similar studies including patients with commercial or Medicare Advantage insurance.[10,27] Given that the Black and White race categories have been validated, it is unlikely

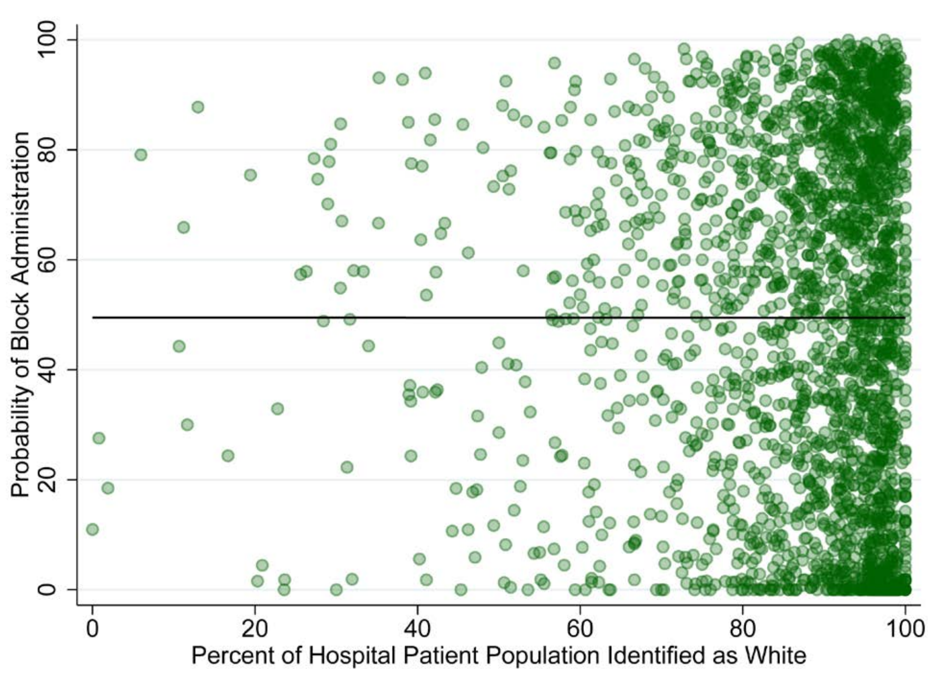

Fig. 1. Unadjusted hospital-level probability of use of regional anesthesia for total knee arthroplasty, by percentage of patient population identified as White. The figure shows the unadjusted probability of a patient at a given hospital receiving a regional anesthetic, plotted against the proportion of White patients (of all patients in our sample) treated at that hospital. The total number of hospitals included in our sample was 2,507, with wide variability in block administration (median, 51%; interquartile range, 18 to 79%). The trendline was generated using univariable linear regression, weighted by the number of cases performed at a given hospital, and calculated with robust standard errors. It represents the change in likelihood of block utilization as the proportion of White patients changed: in other words, for every 10% increase in the proportion of White patients treated at a given hospital, there was a nonsignificant 2.6% increase in the likelihood of block utilization (β = 0.026; 95% CI, –0.102 to 0.153; P = 0.692). This figure therefore illustrates the significant variability in block utilization by hospital that is likely unrelated to race.

that this difference is due to misclassification bias; rather, this difference in the proportion of Black patients potentially stems from varied enrollment patterns of minoritized populations in fee-for-service *versus* Medicare Advantage (*i.e.*, managed care) plans.[28] Our work advances the literature by focusing on patients enrolled in Medicare, a government insurer that pays for the majority of total knee arthroplasties performed in the United States.[16] Our findings suggest that the Medicare fee-for-service population, enrolled based on uniformly consistent eligibility criteria, may exhibit lower incidence of race-related disparities in care, as has been suggested by other work.[29] A potential mechanism for this is that Medicare—by providing universal health insurance coverage for adults greater than 65 yr of age and basing payments on merit-based incentives—may decrease personal cost-related barriers to care and improve access to high quality, evidence-based healthcare. While these findings imply that being enrolled in fee-for-service Medicare may help ameliorate known racial disparities in analgesic care for total knee arthroplasty, they may not necessarily extend to patients enrolled in other forms of insurance. Further, given the limitations of the claims data, it is not clear whether these findings can be extrapolated to intraoperative management (*i.e.*, use of neuraxial anesthesia for intraoperative surgical anesthesia) during total knee arthroplasty.

Our exploratory analysis on patients categorized as Other race (encompassing Hispanic, Asian/Pacific Islander, Native American, other, and unknown) also did not find significant differences in use of regional anesthesia compared to White patients. Given known threats to the validity of the Medicare race variable for those included in the Other race category,[19,30] we repeated our analysis using the Medicare Research Triangle Institute race variable, which replicated the findings from our primary analysis. One recent study on lower extremity total joint arthroplasties based on a national all-payer database reported findings that diverged from ours. These investigators found that both Black and Other (*i.e.*, not White, Black, or Asian) patients were less likely to be exposed to a bundle of evidence-based perioperative practices, including multimodal analgesia, antiemetics, and physical therapy, among others.[31] While this study implied that differences may exist in care for some minoritized groups, it was based on a

Table 3. Proportion of Patients Who Received Regional Anesthesia for Postoperative Pain, by Selected Hospital Characteristics

Hospital Characteristics		Utilization of Regional Anesthesia, Overall and by Hospital Quartile										
		Overall			Hospital Quartile 1 (N* = 627)		Hospital Quartile 2 (N = 627)		Hospital Quartile 3 (N = 626)		Hospital Quartile 4 (N = 627)	
	N* (%)	% (SD)	*P* Value	Hedges' g	White, % (SD)	Black, % (SD)	White, % (SD)	Black, % (SD)	White, % (SD)	Black, % (SD)	White, % (SD)	Black, % (SD)
Total	2,507 (100.0)	52.1 (50.0)	Full cohort		6.0 (23.8)	7.1 (25.8)	35.3 (47.8)	36.1 (48.0)	66.0 (47.4)	66.1 (47.3)	89.9 (30.1)	88.9 (31.4)
Surrounding population density												
Urban	1,890 (75.4)	53.3 (49.9)	Reference		6.2 (24.1)	7.4 (26.2)	34.9 (47.7)	35.6 (47.9)	65.8 (47.4)	65.6 (47.5)	90.0 (30.0)	89.2 (31.1)
Rural	617 (24.6)	44.6 (49.7)	< 0.001†	0.17	5.3 (22.4)	5.5 (22.8)	38.0 (48.6)	43.2 (49.6)	66.9 (47.1)	69.6 (46.0)	89.4 (30.8)	85.7 (35.0)
Number of beds												
< 100	661 (26.4)	51.1 (50.0)	Reference		5.2 (22.2)	5.8 (23.3)	35.7 (47.9)	37.9 (48.6)	68.4 (46.5)	66.6 (47.2)	90.4 (29.4)	89.5 (30.6)
100 to 400	1,363 (54.4)	50.9 (50.0)	0.154	0.01	6.1 (23.9)	6.8 (25.2)	35.3 (47.8)	35.3 (47.8)	65.8 (47.4)	65.8 (47.5)	89.5 (30.7)	88.7 (31.7)
> 400	483 (19.3)	54.6 (49.8)	< 0.001†	0.07	6.6 (24.8)	8.0 (27.1)	35.1 (47.7)	36.7 (48.2)	64.8 (47.8)	66.4 (47.3)	90.2 (29.7)	89.1 (31.2)
Region, U.S. Census Bureau												
West	484 (19.3)	46.6 (49.88)	Reference		6.4 (24.6)	6.6 (24.8)	34.1 (47.4)	36.0 (48.0)	65.9 (47.4)	62.1 (48.6)	89.3 (30.9)	91.7 (27.7)
Midwest	709 (28.3)	52.6 (49.9)	< 0.001†	0.12	5.4 (22.6)	5.6 (23.0)	35.5 (47.9)	36.5 (48.2)	65.2 (47.6)	64.4 (47.9)	89.3 (30.9)	88.5 (32.0)
South	911 (36.3)	52.4 (49.9)	< 0.001†	0.12	6.0 (23.8)	7.1 (25.6)	35.2 (47.8)	36.3 (48.1)	66.5 (47.2)	66.8 (47.1)	90.2 (29.7)	88.4 (32.0)
Northeast	403 (16.1)	56.3 (49.6)	< 0.001†	0.20	6.5 (24.6)	9.3 (29.0)	36.7 (48.2)	34.4 (47.5)	66.6 (47.2)	67.1 (47.0)	90.6 (29.2)	90.5 (29.4)
Ownership												
For-profit	449 (17.9)	52.4 (49.6)	Reference		6.1 (23.8)	5.9 (23.6)	35.1 (47.7)	33.6 (47.2)	67.0 (47.0)	65.9 (47.4)	90.6 (29.2)	88.4 (32.0)
Nonprofit	1,362 (54.3)	52.0 (50.0)	0.022†	0.01	5.8 (23.5)	7.7 (26.7)	35.5 (47.9)	36.5 (48.1)	65.5 (47.5)	65.6 (47.5)	89.8 (30.2)	89.0 (31.3)
Government	339 (13.5)	55.0 (49.8)	< 0.001†	0.05	7.6 (26.5)	8.2 (27.5)	36.9 (48.3)	42.7 (49.5)	67.2 (46.9)	67.1 (47.0)	91.6 (27.8)	89.1 (31.2)
Other	357 (14.2)	49.7 (50.0)	< 0.001†	0.06	5.6 (22.9)	3.5 (18.3)	33.5 (47.2)	30.9 (46.2)	64.9 (47.7)	67.1 (47.0)	88.4 (32.0)	89.1 (31.2)
Academic status												
Teaching	527 (21.0)	53.9 (49.9)	Reference		5.9 (23.6)	6.7 (25.0)	31.5 (46.4)	33.0 (47.0)	65.0 (47.7)	69.4 (46.1)	90.8 (28.9)	89.9 (30.1)
Nonteaching	1,980 (79.0)	51.6 (50.0)	< 0.001†	0.05	6.0 (23.8)	7.3 (26.0)	36.2 (48.1)	37.2 (48.4)	66.2 (47.3)	64.8 (47.8)	89.7 (30.4)	88.6 (31.9)

*N = number of hospitals. †Significant at the $P < 0.05$ level.

The table presents the results of an exploratory analysis identifying the proportion of patients who received regional anesthesia for postoperative pain, stratified by hospital characteristics as identified in the Medicare Provider of Services file. Regional anesthesia utilization was calculated overall across all hospitals in each category and divided into White and Black race categories across hospital quartile by proportion of patients who received regional anesthesia for postoperative pain. The column titled "Overall" presents point estimates as well as results of two-sided *t* tests used to assess for statistically significant differences within category type, along with Hedges' g standardized differences. Hedges' g is the difference between the means of two groups divided by the population standardized difference, with small differences associated with values of less than 0.2, moderate differences with values 0.2 to 0.5, and large differences with values greater than 0.5.[25] Hospital ownership was identified as nonprofit (church or private not-for-profit), for-profit (private for-profit), governmental (federal, state, local, or hospital district or authority), or other (physician ownership, tribal, or other). Hospital academic status was assigned based on the presence of at least one allopathic medical residency program. The proportion of White *versus* Black patients who received regional anesthesia generally did not vary by more than 5% age points within hospital categories and quartiles. However, regional anesthesia administration did vary by 10% across some hospital categories (urban *vs.* rural; U.S. region), with associated small to moderate differences as reflected by the Hedges' g standardized differences.

data set with an unvalidated race variable, and it evaluated a bundle of practices as a binary outcome rather than focusing specifically on the use of regional anesthesia for postoperative pain. Further, that study's overall frequency of peripheral nerve blockade (ranging from 14 to 21%) was much lower than has been previously reported in other studies.[12] Thus, there remains a gap in our knowledge on quality and equity in total knee arthroplasty anesthetic care for patients in some minoritized populations. Future investigations using data sets that have validated and more granular data for other racial and ethnic subgroups may clarify which groups could benefit most from interventions to improve quality of care.

Finally, our findings demonstrating hospital-level variation in block administration are important because they suggest that systemic factors could be targeted in efforts to increase the utilization of evidence-based postoperative analgesia. Our findings in Medicare beneficiaries are in alignment with other studies that have also shown that hospital-level factors[17] may predict whether patients are administered blocks. While exploratory, our analysis of individual hospital characteristics suggests that some types of hospitals (*e.g.*, rural hospitals and those in the Western United States) may provide regional anesthesia for postoperative pain less frequently and may warrant particular attention in research and interventions aimed at promoting high-quality, equitable care. These efforts are particularly pressing and challenging given that—although patients' insurers may cover surgical care at several hospitals—in reality, patients' choices in where they undergo surgery may be extremely limited. Indeed, a recent national analysis of hospitals found that Medicare-insured patients with higher social vulnerability, defined by socioeconomic status, household factors, personal characteristics (minority status and language), and housing type and transportation, were less likely to live in a hospital referral region with a high-quality hospital for hip and knee replacement surgery.[32] This study specifically focused on the Centers for Medicare and Medicaid Services outcome measure of 90-day postsurgical complications and implied uneven and inequitable distributions of hospitals that provide high-quality joint arthroplasty care. Taken in this context, our study suggests that patients may also be constrained by geography in access to high-quality, evidence-based anesthesia care for total knee arthroplasty.

Our study should be viewed considering its limitations. First, as an observational study based on claims data, our analyses are subject to residual confounding related to unobservable medical factors or to regional anesthetics that were administered but nonbillable (*e.g.*, if they were classified by the anesthesiologist as only for intraoperative analgesia). We controlled for unobserved factors at the hospital level by including hospital fixed effects, but this method would not account for all types of residual confounding. Second, while the race variable in Medicare claims data has been validated for the White and Black categories, it has low sensitivity for other racial and ethnic groups; thus, we focused our analyses on the validated categories only. We also checked for robustness of our findings by reclassifying patients in the Other category to White and Black in several ways and by using the alternate Medicare Research Triangle Institute race variable. Third, given that race is intricately related to socioeconomic status, educational level, and many other sociodemographic factors in the United States, it is possible that we were unable to isolate the effects of race on our outcomes. Fourth, conclusions from our data are limited to the years of the study period, which ended in 2016: the volume of regional anesthesia for total knee arthroplasty has increased since then,[33] and it is possible that disparities at the patient or hospital level may have changed in the intervening period. Fifth, given our analytic approach, we excluded approximately 3% of inpatient total knee arthroplasty surgeries because they occurred at hospitals with low surgical volume; this also resulted in the exclusion of 33% of hospitals overall. Thus, it is possible that disparities in analgesic care based on race may exist in those lower-volume hospitals, which comprise a significant proportion of facilities performing total knee arthroplasties. Finally, while our exploratory analysis identified some hospital characteristics that may explain hospital-level variation in regional anesthesia utilization, that analysis was limited to basic characteristics supplied by Medicare and was unable to evaluate more granular hospital-level information such as presence of subspecialty-trained regional anesthesiologists or availability of up-to-date equipment for administration of regional blocks.

Despite these study limitations, our findings provide evidence that systemic factors play a role in existing variation in analgesic care for total knee arthroplasty. First, Medicare insurance status may alleviate the previously reported racial disparities in total knee arthroplasty care for patients who are commercially insured. Second, the hospital where surgery occurs may play a prominent role in whether a patient is administered regional anesthesia. In both cases, changes at the health policy and hospital level have potential to make notable improvements in the quality of care experienced by large populations of patients.

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Competing Interests

Dr. Sun is on the advisory board of Lucid Lane, LLC (Los Altos, California), and reports receiving consulting fees

unrelated to this work from Analysis Group. Dr. Memtsoudis reports being a partner at Parvizi Surgical Innovations, LLC (Philadelphia, Pennsylvania), and an owner of SGM Consulting, LLC (Rumson, New Jersey), both positions unrelated to this work. The other authors declare no competing interests.

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Supplemental Digital Content

Supplemental Figure 1. Flowchart of Sample Construction, https://links.lww.com/ALN/D362
Supplemental Table 1. Primary Unadjusted, Adjusted, and Sensitivity Analyses Estimating Probability of Regional Anesthesia Utilization, https://links.lww.com/ALN/D363
Supplemental Table 2. Sensitivity Analysis with Additional Racial and Ethnic Categories, https://links.lww.com/ALN/D364

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