

Anesthetic Care for Orthopedic Patients

Is There a Potential for Differences in Care?

Stavros G. Memtsoudis, M.D., Ph.D., Jashvant Poeran, M.D., Ph.D., Nicole Zubizarreta, M.P.H.,
Rehana Rasul, M.A., M.P.H., Mathias Opperer, M.D., Madhu Mazumdar, Ph.D.

ABSTRACT

Background: Differences in health care represent a major health policy issue. Despite increasing evidence on the mediating role of anesthesia type used for surgery on perioperative outcome, there is a lack of data on potential care differences in this field. The authors aimed to determine whether anesthesia practice (use of neuraxial anesthesia [NA] or peripheral nerve block [PNB]) differs by patient and hospital factors.

Methods: The authors extracted data on $n = 1,062,152$ hip and knee arthroplasty procedures from the Premier Perspective database (2006 to 2013). Multilevel multivariable logistic regression models measured associations (odds ratios [ORs] and 95% CIs) between patient/hospital factors and NA or PNB use.

Results: Of all patients, 22.2% ($n = 236,083$) received NA and 17.9% ($n = 189,732$) received PNB. Lower adjusted odds for receiving NA were seen for black patients (OR, 0.88; 95% CI, 0.86 to 0.91) and those on Medicaid (OR, 0.78; 95% CI, 0.74 to 0.82) or without insurance (OR, 0.89; 95% CI, 0.81 to 0.98). Furthermore, teaching hospitals (compared with non-teaching hospitals) had lower adjusted odds for NA utilization (OR, 0.35; 95% CI, 0.14 to 0.89). Although generally similar patterns were seen for PNB utilization, the main difference was that particularly Hispanic patients were less likely to receive PNB compared with white patients (OR, 0.60; 95% CI, 0.56 to 0.65). Sensitivity analyses generally validated our results.

Conclusions: Significant differences exist in the provision of regional anesthetic care with factors such as race and insurance type being important determinants of anesthetic practice. Further and in-depth research is needed to fully assess the background of these differences. (**ANESTHESIOLOGY 2016; 124:608-23**)

DIFFERENCES in health care based on patient-specific factors represent a major problem for the healthcare system and society as a whole as they are unjust, unethical, and costly.¹ Much effort has been expended to study factors associated with and reasons for this phenomenon in many fields of medicine with the goal to reduce its prevalence and its associated negative medical and societal consequences.²⁻⁵ Racial and ethnic differences in the treatment of pain have been well documented alongside differences in the use of neuraxial labor analgesia.^{6,7} However, studies using large databases and those assessing differences in other fields of anesthesia practice where regional anesthesia is widely used and may be associated with improved outcomes remain sporadic.^{8,9} Reasons for such lack of data are manifold but include the fact that, until relatively recently, population-based data needed for such analyses were unavailable. With the evolution of large national databases containing anesthesia-related information, such research is now possible and

What We Already Know about This Topic

- Provision of regional anesthetic care by race, insurance type, and type of healthcare facility has been minimally examined

What This Article Tells Us That Is New

- In a review of more than 1 million hip and knee arthroplasty procedures in the Premier Perspective database, use of neuraxial anesthesia was considerably less (odds ratio [OR], 0.35) in teaching *versus* nonteaching hospitals and moderately less for black patients (OR, 0.88), those on Medicaid (OR, 0.78), and those without insurance (OR, 0.89)

necessary to take first steps to establish if significant differences in care and the potential for differences related to patient and healthcare system factors do indeed exist.

The importance of such data has to be viewed in the context of recent publications suggesting that the type of anesthesia used for surgical procedures may significantly affect the risk for complications and negative economic

This article is featured in "This Month in Anesthesiology," page 1A. S.G.M. helped design the study, assisted in interpretation of analyses, and wrote the first draft of the manuscript and has seen the original study data, reviewed the analysis of the data, and is the author responsible for archiving the study files. J.P. helped in analyzing and interpreting the data and writing the manuscript. N.Z. helped in data management, data analysis for the revisions, creation of tables and appendices, and drafting the revised versions of the manuscript. R.R. helped in data management, data analysis, creation of tables and appendices, and writing of the methods section of the manuscript. M.O. helped in analyzing and interpreting the data and writing the manuscript. M.M. helped in reviewing the analyses and interpretation of data and helped to revise the manuscript.

Submitted for publication March 10, 2015. Accepted for publication November 19, 2015. From the Department of Anesthesiology, Hospital for Special Surgery, New York, New York (S.G.M., M.O.); and Department of Population Health Science and Policy, Institute for Healthcare Delivery Science, Icahn School of Medicine at Mount Sinai, New York, New York (J.P., N.Z., R.R., M.M.).

Copyright © 2016, the American Society of Anesthesiologists, Inc. Wolters Kluwer Health, Inc. All Rights Reserved. Anesthesiology 2016; 124:608-23

outcomes.^{10–12} Specifically, an increasing body of evidence suggests that neuraxial anesthesia may indeed lead to superior outcomes compared with general anesthesia.^{10–12} This observation has been best documented in the ever increasing joint arthroplasty population, which is expected to reach 3.5 million per annum in the United States alone by the year 2030.¹³ Although patient subgroup differences in this population have been demonstrated regarding both the odds of undergoing an arthroplasty¹⁴ and the outcomes after the procedure,¹⁵ less is known about the factors affecting the process of anesthetic care that might mitigate particularly the latter.

Therefore, we utilized a large national database containing anesthesia-related information to study whether anesthesia practice (the use of neuraxial anesthesia and the use of peripheral nerve block) differs by patient factors including age, race, gender, and insurance type as well as healthcare system-related factors such as hospital size, location, and teaching status.

We hypothesized that significant differences in anesthetic care provided to members of different patient groups and in different healthcare settings exist. If identified, these data could be used to launch studies into the reasons for and consequences of potential differences in care.

Materials and Methods

Institutional Review Board

Data used in this study were deidentified according to the Health Insurance Portability and Accountability Act,¹⁶ and therefore, this study was exempt from individual consent requirements by the Institutional Review Board of the Hospital for Special Surgery (New York, New York; #2012-050-CR2) and the Mount Sinai Medical Center (New York, New York; #14-00647).

Data Source and Study Design

The Premier Perspective database (Premier Inc., USA) containing hospital discharges from January 2006 to December 2013 was accessed for this retrospective analysis. It contains all diagnostic and procedural data from International Classification of Diseases, 9th revision, Clinical Modification codes, Current Procedural Terminology codes, and standardized billing items for approximately 20 to 25% of US hospitals. The number of hospitals in this dataset depends on the cohort requested and purchased; in this study, the dataset contained 540 hospitals. Although the Midwest, Northeast, and Northwest are also represented, the Southeastern United States is the most represented region. Our study goal was defined, and hypotheses were generated *a priori*.

Study Sample

All adult inpatients with an elective primary total hip or knee arthroplasty (THA/TKA), as indicated by International Classification of Diseases, 9th revision, Clinical Modification

codes 81.51 and 81.54, respectively, were considered for this study. Excluded were those THA procedures undertaken for the treatment of fractures. Patients with missing information on gender ($n = 69$), discharge status ($n = 498$), or those who underwent multiple arthroplasties during a single admission ($n = 212$) were excluded. A flowchart depicting the study sample is provided in appendix 1.

Study Variables

Primary outcome variables were (1) use of neuraxial anesthesia and (2) use of a peripheral nerve block. These were determined from billing and procedural codes as reported by our study group.¹⁷ We combined spinal and epidural anesthesia into neuraxial because differential information was not reliably available. Moreover, we were interested in determining the choice to use regional anesthesia in a wider sense. In defining our outcome variables, the main assumption we make is that if there was no billing for neuraxial anesthesia or peripheral nerve block, then there indeed was no use of either of these techniques. As there are only few other large databases that contain this information on anesthesia type, it is difficult to test the validity of this assumption. However, one study using the National Anesthesia Clinical Outcomes Registry data of the Anesthesia Quality Institute (a database created specifically for this purpose) found a rate of neuraxial anesthesia of 31.3%, which is only moderately higher than the rate found in our dataset.¹⁸ For peripheral nerve blocks, there appears to be inadequate information in available population-based studies to compare our numbers to. In addition, we were not able to reliably distinguish single-shot techniques from catheter approaches.

The patient variables that were considered to be potentially important determinants in respect to care differences¹⁹ were age, gender, race, and insurance type. Race was categorized as white, black, Hispanic, and other. Insurance type was categorized as commercial, Medicaid, Medicare, uninsured, and other (*e.g.*, other government payors). Healthcare-related variables included hospital location (rural, urban), hospital area (Midwest, Northeast, South, and West), hospital size (less than 300, 300 to 499, and more than or equal to 500 beds), and hospital teaching status. In addition, procedure-related variables were studied: type of procedure (THA, TKA), use of general anesthesia, use of anticoagulants (on the day of procedure: aspirin, warfarin, heparin, other, more than one medication, none), and year of procedure. To account for overall comorbidity burden, the updated Deyo adaptation of the Charlson comorbidities was used.²⁰

Statistical Analysis

Unadjusted Analysis. The use of neuraxial anesthesia and peripheral nerve block by study variables was described using mean and SD for continuous variables and percentages for categorical variables. Associations between groups

were assessed using the chi-square test and the two-sample *t* test for categorical and continuous variables, respectively.

Multilevel Logistic Regression Analysis. To measure the multivariable association between study variables and the use of neuraxial anesthesia and peripheral nerve block, two separate multilevel multivariable logistic regressions were specified. Each model included a random intercept term that varies at the level of each hospital and accounts for correlation of patients within hospitals. Only hospitals with more than 50 patients were included to assure a sufficient sample size per cluster. All patient-, healthcare-, and procedure-related variables (except for anticoagulant use as we do not know whether it was ordered before or after the decision for regional anesthesia) and individual Deyo–Charlson comorbidities (with significance threshold $P < 0.15$, see also appendix 2) were included in the main model for the outcomes of neuraxial anesthesia and peripheral nerve block.

To allow for a more specified description of potential differences in care by race and insurance status, the multivariable models were fitted with an interaction to assess differences in care between race groups within insurance categories. As has been suggested, an interaction may exist, and at least in theory sufficient insurance coverage may help reduce differences in care.²¹ In addition, as there might be interdependence in the choice for regional anesthesia (either neuraxial anesthesia or peripheral nerve block), we fitted an additional model with the outcome of receiving either one of these regional anesthetic techniques as an exploratory analysis to assess whether similar factors arise suggesting a potential for differences in care.

Given the large sample size, we present adjusted odds ratios (ORs), 95% CIs and *P* values together as a measure to allow the reader to interpret overall significance. For models containing interactions, Bonferroni-corrected ORs

and *P* values are presented to account for multiple testing. Herein, we take into account the specific number of tests based on the interaction categories (race × insurance status or insurance status × race). The intraclass correlation, which explains the percentage of the total variance in the outcome accounted for by differences between hospitals, is also presented for each model.

All analyses were performed using SAS v9.3 statistical software (SAS Institute, Cary, USA); the GLIMMIX procedure was used for multilevel regression analyses. Code is available on request.

Results

We identified a total of 1,062,152 elective hip and knee arthroplasty procedures performed in 540 hospitals. Of those, 22.2% (*n* = 236,083) received a neuraxial anesthetic and 17.9% (*n* = 189,732) received a peripheral nerve block.

Unadjusted Analyses

Table 1 depicts the use of neuraxial anesthesia by study variables; its utilization decreased over the years (23.6% in 2006 *vs.* 19.6% in 2013); $P < 0.0001$. Interestingly, there were no differences in gender or Deyo–Charlson comorbidity index between groups.

Table 2 depicts the use of peripheral nerve blocks following the same setup of the previous table. Although there were (small) differences in gender and Deyo–Charlson comorbidity index between groups, hospital factors appeared to play a smaller role in this setting compared with neuraxial anesthesia. The use of peripheral nerve blocks increased from 2006 (13.3%) to 2013 (19.5%); $P < 0.0001$. Information on the use of neuraxial anesthesia and peripheral nerve blocks for THA and TKA patients separately can be found in appendices 3 to 6.

Table 1. Study Variables by Use of Neuraxial Anesthesia

	Use of Neuraxial Anesthesia			<i>P</i> Value*
	Yes (<i>n</i> = 236,083), <i>N</i>	No (<i>n</i> = 826,069), <i>N</i>	%	
Patient related				
Age (yr)				
< 45	5,179	24,221	17.6	< 0.0001
45–54	26,371	105,576	20.0	
55–64	66,521	241,051	21.6	
65–74	79,917	270,205	22.8	
75–99	58,095	185,016	23.9	
Gender				
Female	142,929	501,952	22.2	0.05135
Male	93,154	324,117	22.3	
Race				
White	182,800	622,585	22.7	< 0.0001
Black	12,810	61,791	17.2	
Hispanic	3,482	11,162	23.8	
Other	36,991	130,531	22.1	
Mean Deyo–Charlson comorbidity index†	0.43 (0.89)	0.43 (0.90)	—	0.3037

(Continued)

Table 1. (Continued)

	Use of Neuraxial Anesthesia		%	P Value*
	Yes (n = 236,083), N	No (n = 826,069), N		
Healthcare related				
Insurance type				
Commercial	86,695	318,147	21.4	< 0.0001
Medicaid	4,579	23,883	16.1	
Medicare	136,175	452,050	23.2	
Uninsured	1,270	4,477	22.1	
Other	7,364	27,512	21.1	
Hospital location				
Urban	196,346	740,827	21.0	< 0.0001
Rural	39,737	85,242	31.8	
Hospital size				
< 300 beds	85,678	301,790	22.1	< 0.0001
300–499 beds	102,287	288,382	26.2	
≥ 500 beds	48,118	235,897	16.9	
Hospital teaching status				
Nonteaching	171,423	468,975	26.8	< 0.0001
Teaching	64,660	357,094	15.3	
Hospital area				
Midwest	60,450	154,581	28.1	< 0.0001
Northeast	24,278	181,527	11.8	
South	94,865	336,516	22.0	
West	56,490	153,445	26.9	
Procedure related				
Type of procedure				
Primary knee arthroplasty	164,925	554,501	22.9	< 0.0001
Primary hip arthroplasty	71,158	271,568	20.8	
Use of general anesthesia				
Yes	120,783	614,496	16.4	< 0.0001
No	115,300	211,573	35.3	
Use of peripheral nerve block				
Yes	51,635	138,097	27.2	< 0.0001
No	184,448	687,972.0	21.1	
Use of anticoagulants				
None	12,567	53,719	19.0	< 0.0001
Antiplatelets: aspirin	10,909	57,700	15.9	
Anticoagulants: warfarin	64,390	214,484	23.1	
Anticoagulants: heparin	60,150	222,049	21.3	
Anticoagulants: other	23,248	87,994	20.9	
> 1 of above	64,819	190,123	25.4	
Year of procedure				
2006	24,086	77,875	23.6	< 0.0001
2007	25,411	84,109	23.2	
2008	25,835	88,915	22.5	
2009	30,590	100,781	23.3	
2010	35,226	110,625	24.2	
2011	34,180	118,843	22.3	
2012	31,623	125,300	20.2	
2013	29,132	119,621	19.6	

* Chi-square test for categorical variables, t test for continuous variables. † Continuous variable are represented as mean (SD) instead of N (%).

Multivariable Analyses

The multivariable multilevel regression analyses are shown in table 3 for the outcomes of neuraxial anesthesia and peripheral nerve block. These models do not include the “hospital area” variable because including this variable resulted in

an unstable model. Age was associated with higher odds for receiving either neuraxial anesthesia (OR, 1.07; 95% CI, 1.07 to 1.08) or a peripheral nerve block (OR, 1.05; 95% CI, 1.04 to 1.06); both $P < 0.0001$. Lower adjusted odds for receiving neuraxial anesthesia were seen for black patients

(OR, 0.88; 95% CI, 0.86 to 0.91) and those with noncommercial insurance, particularly Medicaid (OR, 0.78; 95% CI, 0.74 to 0.82) and those with no insurance (OR, 0.89; CI, 0.81 to 0.98). Hospital factors appeared to matter less in their associations with the use of neuraxial anesthesia. When comparing the odds for receiving peripheral nerve blocks (table 3; right half) with neuraxial anesthesia, the main difference included the lower odds for Hispanic patients (OR, 0.60; 95% CI, 0.56 to 0.65). The c-statistics of the models were high (0.94 for neuraxial anesthesia and 0.96 for peripheral nerve block), suggesting very good discrimination. Moreover, the intraclass correlation values suggested a substantial role of the hospital level effects in explaining

variance in neuraxial anesthesia (0.75) and peripheral nerve block (0.86).

Results from the exploratory model with the outcome of receiving either one of the regional anesthetic techniques can be found in appendix 7. In summary, although similar patient factors arose suggesting a potential for differences in care, hospital factors appeared to matter less. In addition, we have added a sensitivity analysis by repeating the analyses depicted in table 3 with a restricted cohort of only those patients with a known type of anesthesia (n = 850,579) to test the validity of our assumption that patients who were not billed for neuraxial anesthesia or peripheral nerve blocks did not receive those. The sensitivity analyses (appendix 8)

Table 2. Study Variables by Use of Peripheral Nerve Block

	Use of Peripheral Nerve Block			
	Yes (n = 189,732), N	No (n = 872,420), N	%	P Value*
Patient related				
Age (yr)				
< 45	3,607	25,793	12.3	< 0.0001
45–54	21,248	110,699	16.1	
55–64	55,947	251,625	18.2	
65–74	65,759	284,363	18.8	
75–99	43,171	199,940	17.8	
Gender				
Female	116,652	528,229	18.1	< 0.0001
Male	73,080	344,191	17.5	
Race				
White	153,399	651,986	19.0	< 0.0001
Black	12,167	62,434	16.3	
Hispanic	2,294	12,350	15.7	
Other	21,872	145,650	13.1	
Mean Deyo–Charlson comorbidity index†	0.42 (0.88)	0.44 (0.90)	—	0.003
Healthcare related				
Insurance type				
Commercial	71,934	332,908	17.8	< 0.0001
Medicaid	4,017	24,445	14.1	
Medicare	107,153	481,072	18.2	
Uninsured	688	5,059	12.0	
Other	5,940	28,936	17.0	
Hospital location				
Urban	167,461	769,712	17.9	0.67133
Rural	22,271	102,708	17.8	
Hospital size				
< 300 beds	52,748	334,720	13.6	< 0.0001
300–499 beds	73,240	317,429	18.7	
≥ 500 beds	63,744	220,271	22.4	
Hospital teaching status				
Nonteaching	108,220	532,178	16.9	< 0.0001
Teaching	81,512	340,242	19.3	
Hospital area				
Midwest	50,100	164,931	23.3	< 0.0001
Northeast	23,747	182,058	11.5	
South	89,235	342,146	20.7	
West	26,650	183,285	12.7	

(Continued)

Table 2. (Continued)

	Use of Peripheral Nerve Block			P Value*
	Yes (n = 189,732), N	No (n = 872,420), N	%	
Procedure related				
Type of procedure				
Primary knee arthroplasty	158,703	560,723	22.1	< 0.0001
Primary hip arthroplasty	31,029	311,697	9.1	
Use of general anesthesia				
Yes	111,648	623,631	15.2	< 0.0001
No	78,084	248,789	23.9	
Use of neuraxial anesthesia				
Yes	51,635	184,448	21.9	< 0.0001
No	138,097	687,972	16.7	
Use of anticoagulants				
None	11,082	55,204	16.7	< 0.0001
Antiplatelets: aspirin	12,806	55,803	18.7	
Anticoagulants: warfarin	47,614	231,260	17.1	
Anticoagulants: heparin	44,226	237,973	15.7	
Anticoagulants: other	22,918	88,324	20.6	
> 1 of above	51,086	203,856	20.0	
Year of procedure				
2006	13,544	88,417	13.3	< 0.0001
2007	15,423	94,097	14.1	
2008	17,227	97,523	15.0	
2009	22,321	109,050	17.0	
2010	28,878	116,973	19.8	
2011	31,446	121,577	20.5	
2012	31,905	125,018	20.3	
2013	28,988	119,765	19.5	

* Chi-square test for categorical variables, *t* test for continuous variables. † Continuous variable are represented as mean (SD) instead of N (%).

Table 3. Multilevel Multivariable Model Depicting Patient and Healthcare Variables for Outcomes of Use of Neuraxial Anesthesia (Left) and Use of Peripheral Nerve Block (Right)

	Outcome: Use of Neuraxial Anesthesia			Outcome: Use of Peripheral Nerve Block		
	OR*	95% CI	P Value	OR†	95% CI	P Value
Age (continuous)	1.07	1.07–1.08	< 0.0001	1.05	1.04–1.06	< 0.0001
Race (reference: white)						
Black	0.88	0.86–0.91	< 0.0001	0.94	0.92–0.97	0.000
Hispanic	1.05	0.99–1.12	0.123	0.60	0.56–0.65	< 0.0001
Other	1.27	1.24–1.30	< 0.0001	0.96	0.93–0.99	0.011
Insurance type (reference: commercial)						
Medicaid	0.78	0.74–0.82	< 0.0001	0.86	0.82–0.91	< 0.0001
Medicare	0.92	0.90–0.94	< 0.0001	0.92	0.90–0.94	< 0.0001
Uninsured	0.89	0.81–0.98	0.022	0.89	0.79–1.00	0.052
Other	1.08	1.04–1.13	0.000	0.97	0.93–1.01	0.141
Hospital location (reference: urban)						
Rural	1.48	0.56–3.91	0.433	0.45	0.16–1.25	0.133
Hospital teaching status (reference: nonteaching)						
Teaching	0.35	0.14–0.89	0.027	0.20	0.08–0.54	0.001

* Adjusted for gender, use of general anesthesia, year of procedure, type of procedure, hospital size, myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, rheumatologic disease, mild liver disease, moderate/severe liver disease, diabetes, diabetes with chronic complications, hemiplegia or paraplegia, renal disease, any malignancy, metastatic solid tumor, and AIDS. † Adjusted for gender, use of general anesthesia, year of procedure, type of procedure, hospital size, chronic pulmonary disease, rheumatologic disease, peptic ulcer disease, mild liver disease, moderate/severe liver disease, diabetes, diabetes with chronic complications, hemiplegia or paraplegia, renal disease, any malignancy, metastatic solid tumor, and AIDS.

AIDS = acquired immunodeficiency syndrome; OR = odds ratio.

did not reveal any major differences compared with our main analyses.

Table 4 details the outcome of the same models while adding the insurance status \times race interaction, which itself was significant for both models (both $P < 0.005$). Lower odds for neuraxial anesthesia were seen for black patients who were commercially insured and those on Medicare, whereas the lower odds for peripheral nerve blocks among Hispanic patients were seen for almost all insurance types.

Discussion

In this study of population-based data derived from more than 500 US hospitals, we identified significant differences in the utilization of regional anesthetic techniques among patients of different demographics. In this regard, neuraxial anesthesia and peripheral nerve block were less likely to be used in black and Hispanic (*vs.* white) patients and those on Medicaid, Medicare, and no insurance (compared with commercially insured patients). Moreover, increasing age was associated with increased utilization of neuraxial anesthesia and peripheral nerve block. Compared with patient factors, hospital factors appeared to play a less important role in utilization of both regional anesthetic techniques. Sensitivity analyses taking into account missing information on anesthesia type generally validated our results.

These findings suggest (although do not prove) that differences in regional anesthetic care may exist among patients undergoing joint arthroplasty. Such differences in medical care have been described to be widely prevalent.²² Unfortunately, despite some attention in the use of labor epidurals,^{6,7,23} this topic has not been thoroughly examined for the practice of anesthesiology. This may be because this field has traditionally not been viewed as a priority in respect to influencing overall patient outcomes. However, this assumption, has been altered significantly in recent years with a number of researchers publishing investigations suggesting benefits of neuraxial anesthesia *versus* a general anesthetic approach in respect to major morbidity and mortality.^{8,10–12,24–26} Such outcome differences have been especially well documented in orthopedic patients who are uniquely amenable to the use of regional anesthesia. Similar benefits have been reported for the use of a peripheral nerve block for improved pain control,^{27,28} a major determinant of patient satisfaction, and the ability to rehabilitate.²⁹ Thus, potential differences in anesthetic care may indeed be more consequential than initially thought.

We identified race and insurance status to be significantly associated with the use of neuraxial anesthesia and peripheral nerve block. Hispanic and black patients and those on Medicare, Medicaid, and with no insurance were less likely to receive regional anesthetic interventions compared with

Table 4. Multilevel Multivariable Model Depicting the Interaction between Insurance Type and Race

Insurance Type \times Race Interaction (Reference: White)	Outcome: Use of Neuraxial Anesthesia			Outcome: Use of Peripheral Nerve Block		
	OR*	95% CI	P Value	OR†	95% CI	P Value
Commercial						
Black	0.85	0.79–0.92	< 0.0001	0.87	0.81–0.94	0.0002
Hispanic	0.99	0.85–1.16	0.942	0.42	0.35–0.50	< 0.0001
Other	1.56	1.48–1.64	< 0.0001	0.98	0.93–1.04	0.470
Medicaid						
Black	1.14	0.92–1.40	0.222	0.75	0.62–0.91	0.0044
Hispanic	1.82	1.18–2.81	0.007	0.45	0.29–0.69	0.0003
Other	1.44	1.17–1.79	0.001	0.91	0.74–1.12	0.380
Medicare						
Black	0.91	0.86–0.98	0.0071	0.99	0.93–1.05	0.625
Hispanic	1.24	1.10–1.40	0.001	0.33	0.28–0.38	< 0.0001
Other	1.72	1.64–1.80	< 0.0001	0.98	0.94–1.03	0.5217
Uninsured						
Black	0.72	0.40–1.30	0.274	0.77	0.46–1.30	0.334
Hispanic	0.83	0.34–2.03	0.687	0.08	0.01–0.88	0.039
Other	1.91	1.32–2.75	0.001	0.86	0.57–1.30	0.479
Other						
Black	0.92	0.76–1.10	0.355	0.90	0.76–1.07	0.245
Hispanic	0.86	0.62–1.19	0.365	0.98	0.73–1.31	0.894
Other	1.02	0.87–1.20	0.805	0.98	0.85–1.14	0.820

* Adjusted for age, gender, hospital location, teaching status, use of general anesthesia, year of procedure, type of procedure, myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, rheumatologic disease, mild liver disease, moderate/severe liver disease, diabetes, diabetes with chronic complications, hemiplegia or paraplegia, renal disease, any malignancy, metastatic solid tumor, and AIDS. † Adjusted for age, gender, hospital location, teaching status, use of general anesthesia, year of procedure, type of procedure, chronic pulmonary disease, rheumatologic disease, peptic ulcer disease, mild liver disease, moderate/severe liver disease, diabetes, diabetes with chronic complications, hemiplegia or paraplegia, renal disease, any malignancy, metastatic solid tumor, and AIDS.

AIDS = acquired immunodeficiency syndrome; OR = odds ratio.

commercially insured patients. These findings are in line with those reported in other medical fields, where significant socioeconomic and racial differences in care have long been pointed out.^{2,3,22} Despite a general paucity in anesthesia-related studies, the few data available are in congruence with our findings. In a study of the use of neuraxial anesthesia for ambulatory hernia repair in the 1990s, our group found that black patients were less likely to receive epidural anesthesia (compared with white patients: OR, 0.36; 95% CI, 0.14 to 0.95).⁸ Although the mentioned study identified female gender to be associated with a reduced likelihood for neuraxial anesthesia use, we did not find such a difference in this analysis.

Advanced age was also found to be a major determinant of the use of neuraxial anesthesia and peripheral nerve block, a finding that has been reported by descriptive analyses.¹⁸ Although speculative, this may reflect anesthesiologists' concern to avoid general anesthetics in older, more frail, individuals who are deemed at risk for pulmonary complications and delirium, which have been linked to the requirement for airway instrumentation and need for larger doses of opioids with general anesthesia.^{22,30} Alternatively, avoiding rare, but potentially devastating side effects, such as postdural puncture headaches among younger individuals, who are known to be more prone to such adversities,³¹ may be another explanation. However, patient attitudes and preference might play an undervalued and underappreciated role in the choice of regional anesthetic techniques and may be partially responsible for the observed differences in regional anesthetic care. Although few studies have linked patient preferences to observed differences in care,³² there is some evidence on the role of patient preferences differing by subgroup in the setting of anesthetic care. Younger age, for example, has been described as a patient-related factor for choosing general over other forms of anesthesia among individuals in hernia repair surgery.³³ In another study looking at patient perceptions of anesthesia in a variety of surgeries, it appeared that female patients were more likely to prefer general anesthesia.³⁴ Interestingly, one of the main drivers of these preferences was related to hearing and seeing the surgery and the fear of feeling pain. Furthermore, the more elaborate literature on care differences in obstetric analgesia offers some insights of differential preferences among patient subgroups; one study found Hispanic women to anticipate the use of neuraxial analgesia at a lower rate compared with other racial/ethnic groups.²³ Given that there is a paucity on data on patient preferences on regional anesthesia, more research in this field is needed, specifically research that focuses on potential differences in preference related to factors traditionally found to be related to care differences, *e.g.*, race, insurance status, or even socioeconomic status.

The multilevel models additionally found a substantial role of unspecified hospital level effects in explaining variance in the use of neuraxial anesthesia and peripheral nerve

blocks. The reasons for these findings have to remain speculative. It has been described that individual practice patterns are influenced by many factors such as practitioners' choice (surgeon and anesthesiologists), which in turn may depend on the comfort and/or training of clinicians.^{35,36} Further, the ability to deal with complications and/or the presence of compatible perioperative care, such as anticoagulation regimens, may be significant factors influencing practice.

Our study results have to be considered in the context of a number of limitations. Those related to the secondary analyses of large databases have been described in much detail and include lack of limited clinical detail, potential for coding bias, and lack of a complete list of confounders. Thus, information that may influence the choice of anesthesia such as contraindications, including physiologic derangements, anatomical abnormalities, and patient and physician wishes, cannot be considered here. The lack of information on these and other unknown factors influencing the choice of anesthesia may result in residual confounding affecting our current estimates. However, despite this limitation, the identified differences in care were based on the patient factors that are generally found in a wide range of other care settings including obstetric analgesia and treatment of pain in other environments.^{6,7} In line with the lack of detailed clinical data, one important missing piece of information in the context of peripheral nerve block provision concerned our inability to accurately identify single-shot techniques from catheter approaches. More detailed clinical data and qualitative studies assessing (the relative importance of) factors influencing the choice for regional anesthetic techniques are needed to fully appraise decision-making in this context. Adding to the limitation of incomplete data, our dataset did not provide information on socioeconomic status, an important variable frequently identified in research that focuses on care differences.

As mentioned earlier, no causality can be inferred from the available data. Although our results do not answer the question of why, they do, however, provide the crucial first step, which is the establishment of the fact that differences in care appear to exist in the field of anesthesiology. To address and minimize the potential for differences in care, researchers and healthcare providers have to be willing to evaluate a large number possibly contributing factors. One important and arguably sensitive one is the potential for bias among healthcare providers. Such unconscious bias has been documented to exist,^{37,38} but recognition is necessary for the design and implementation of strategies to reduce it.

Important next steps to further explore the potential for differences in care are validation of the current results using other data sources and a thorough assessment of factors that affect the decision-making process in the provision of regional anesthetic techniques. This would provide additional insight into what data are needed to appraise the observed differences in provision of anesthetic care.

Moreover, because neuraxial anesthesia and peripheral nerve blocks are frequently seen as “higher quality care,” investigations assessing differences in outcomes (*e.g.*, perioperative outcomes such as thromboembolism, cardiac and pulmonary complications) should be prioritized and linked to studies on differences in the process of anesthetic care provision. When these two aspects can be reliably linked (*i.e.*, differences in anesthetic practices lead to differences in patient outcome), ensuing evaluations should focus on ways to reduce this variation.

In conclusion, significant differences in the provision of regional anesthetic care exist. Factors such as insurance status, race, and age are determinants of anesthetic practice. Although reasons for these differences have to remain speculative, the fact that they appear to exist requires further and in-depth research, especially in the context of data suggesting that the choice of anesthesia type for orthopedic surgery significantly influences perioperative outcome.

Acknowledgments

This study was funded by the Anna Maria and Stephen Kellen Career Development Award (to Dr. Memtsoudis). The study sponsors had no role in the design and conduct of the study; in the collection, analysis, and interpretation of the data; or in the preparation, review, or approval of the manuscript. The views expressed in this article are those of the authors and do not necessarily represent the views of the sponsors or authors' affiliated institutions.

Competing Interests

The authors declare no competing interests.

Correspondence

Address correspondence to Dr. Memtsoudis: Department of Anesthesiology, Hospital for Special Surgery, 535 East 70th Street, New York, New York 10021. memtsoudiss@hss.edu. This article may be accessed for personal use at no charge through the Journal Web site, www.anesthesiology.org.

References

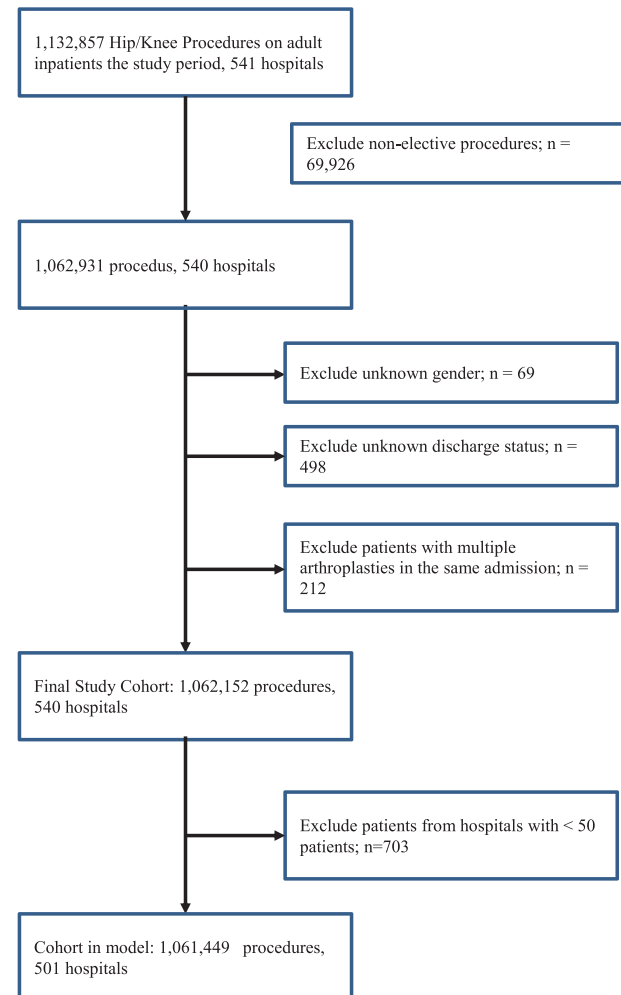
- Betancourt JR, Corbett J, Bondaryk MR: Addressing disparities and achieving equity: Cultural competence, ethics, and health-care transformation. *Chest* 2014; 145:143–8
- Haider AH, Chang DC, Efron DT, Haut ER, Crandall M, Cornwell EE III: Race and insurance status as risk factors for trauma mortality. *Arch Surg* 2008; 143:945–9
- Hauch A, Al-Qurayshi Z, Friedlander P, Kandil E: Association of socioeconomic status, race, and ethnicity with outcomes of patients undergoing thyroid surgery. *JAMA Otolaryngol Head Neck Surg* 2014; 140:1173–83
- Schuster MA, Elliott MN, Kanouse DE, Wallander JL, Tortolero SR, Ratner JA, Klein DJ, Cuccaro PM, Davies SL, Banspach SW: Racial and ethnic health disparities among fifth-graders in three cities. *N Engl J Med* 2012; 367:735–45
- Kulig K, Bingham CO III, Steele LL: Racial, ethnic, and geographic disparities in rates of knee arthroplasty. *N Engl J Med* 2004; 350:305–6
- Meghani SH, Byun E, Gallagher RM: Time to take stock: A meta-analysis and systematic review of analgesic treatment disparities for pain in the United States. *Pain Med* 2012; 13:150–74
- Rust G, Nembhard WN, Nichols M, Omole F, Minor P, Barosso G, Mayberry R: Racial and ethnic disparities in the provision of epidural analgesia to Georgia Medicaid beneficiaries during labor and delivery. *Am J Obstet Gynecol* 2004; 191:456–62
- Memtsoudis SG, Rasul R, Suzuki S, Poeran J, Danninger T, Wu C, Mazumdar M, Vougioukas V: Does the impact of the type of anesthesia on outcomes differ by patient age and comorbidity burden? *Reg Anesth Pain Med* 2014; 39:112–9
- Memtsoudis SG, Besculides MC, Swamidoss CP: Do race, gender, and source of payment impact on anesthetic technique for inguinal hernia repair? *J Clin Anesth* 2006; 18:328–33
- Liu J, Ma C, Elkassabany N, Fleisher LA, Neuman MD: Neuraxial anesthesia decreases postoperative systemic infection risk compared with general anesthesia in knee arthroplasty. *Anesth Analg* 2013; 117:1010–6
- Pugely AJ, Martin CT, Gao Y, Mendoza-Lattes S, Callaghan JJ: Differences in short-term complications between spinal and general anesthesia for primary total knee arthroplasty. *J Bone Joint Surg Am* 2013; 95:193–9
- Rodgers A, Walker N, Schug S, McKee A, Kehlet H, van Zundert A, Sage D, Futter M, Saville G, Clark T, MacMahon S: Reduction of postoperative mortality and morbidity with epidural or spinal anaesthesia: Results from overview of randomised trials. *BMJ* 2000; 321:1493
- Kurtz S, Ong K, Lau E, Mowat F, Halpern M: Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am* 2007; 89:780–5
- Singh JA, Lu X, Rosenthal GE, Ibrahim S, Cram P: Racial disparities in knee and hip total joint arthroplasty: An 18-year analysis of national Medicare data. *Ann Rheum Dis* 2014; 73:2107–15
- Browne JA, Novicoff WM, D'Apuzzo MR: Medicaid payer status is associated with in-hospital morbidity and resource utilization following primary total joint arthroplasty. *J Bone Joint Surg Am* 2014; 96:e180
- US Department of Health and Human Services. Health Information Privacy. Available at: <http://www.hhs.gov/ocr/privacy>. Accessed September 9, 2015
- Memtsoudis SG, Danninger T, Rasul R, Poeran J, Gerner P, Stundner O, Mariano ER, Mazumdar M: Inpatient falls after total knee arthroplasty: The role of anesthesia type and peripheral nerve blocks. *ANESTHESIOLOGY* 2014; 120:551–63
- Fleischut PM, Eskreis-Winkler JM, Gaber-Baylis LK, Giambrone GP, Faggiani SL, Dutton RP, Memtsoudis SG: Variability in anesthetic care for total knee arthroplasty: An analysis from the anesthesia quality institute. *Am J Med Qual* 2015; 30:172–9
- Agency for Healthcare Research and Quality. National Healthcare Disparities Report 2013. Rockville, Agency for Healthcare Research and Quality, 2014. Available at: <http://www.ahrq.gov/sites/default/files/publications/files/2013nhdr.pdf>. Accessed July 11, 2014
- Quan H, Sundararajan V, Halfon P, Fong A, Burnand B, Luthi JC, Saunders LD, Beck CA, Feasby TE, Ghali WA: Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care* 2005; 43:1130–9
- Mahal BA, Ziehr DR, Aizer AA, Hyatt AS, Sammon JD, Schmid M, Choueiri TK, Hu JC, Sweeney CJ, Beard CJ, D'Amico AV, Martin NE, Lathan C, Kim SP, Trinh QD, Nguyen PL: Getting back to equal: The influence of insurance status on racial disparities in the treatment of African American men with high-risk prostate cancer. *Urol Oncol* 2014; 32:1285–91
- Zywiels MG, Prabhu A, Perruccio AV, Gandhi R: The influence of anesthesia and pain management on cognitive dysfunction after joint arthroplasty: A systematic review. *Clin Orthop Relat Res* 2014; 472:1453–66

23. Toledo P, Sun J, Grobman WA, Wong CA, Feinglass J, Hasnain-Wynia R: Racial and ethnic disparities in neuraxial labor analgesia. *Anesth Analg* 2012; 114:172–8
24. Macfarlane AJ, Prasad GA, Chan VW, Brull R: Does regional anesthesia improve outcome after total knee arthroplasty? *Clin Orthop Relat Res* 2009; 467:2379–402
25. Chang CC, Lin HC, Lin HW, Lin HC: Anesthetic management and surgical site infections in total hip or knee replacement: A population-based study. *ANESTHESIOLOGY* 2010; 113:279–84
26. Memtsoudis SG, Sun X, Chiu YL, Nurok M, Stundner O, Pastores SM, Mazumdar M: Utilization of critical care services among patients undergoing total hip and knee arthroplasty: Epidemiology and risk factors. *ANESTHESIOLOGY* 2012; 117:107–16
27. Paul JE, Arya A, Hurlburt L, Cheng J, Thabane L, Tidy A, Murthy Y: Femoral nerve block improves analgesia outcomes after total knee arthroplasty: A meta-analysis of randomized controlled trials. *ANESTHESIOLOGY* 2010; 113:1144–62
28. Stein BE, Srikumaran U, Tan EW, Freehill MT, Wilckens JH: Lower-extremity peripheral nerve blocks in the perioperative pain management of orthopaedic patients: AAOS exhibit selection. *J Bone Joint Surg Am* 2012; 94:e167
29. Chelly JE, Ben-David B, Williams BA, Kentor ML: Anesthesia and postoperative analgesia: Outcomes following orthopedic surgery. *Orthopedics* 2003; 26(8 suppl):s865–71
30. Papaioannou A, Fridakis O, Michaloudis D, Balalis C, Askitopoulou H: The impact of the type of anaesthesia on cognitive status and delirium during the first postoperative days in elderly patients. *Eur J Anaesthesiol* 2005; 22:492–9
31. Lybecker H, Möller JT, May O, Nielsen HK: Incidence and prediction of postdural puncture headache. A prospective study of 1021 spinal anesthetics. *Anesth Analg* 1990; 70:389–94
32. Katz JN: Patient preferences and health disparities. *JAMA* 2001; 286:1506–9
33. Sanjay P, Marioud A, Woodward A: Anaesthetic preference and outcomes for elective inguinal hernia repair: A comparative analysis of public and private hospitals. *Hernia* 2013; 17:745–8
34. Dove P, Gilmour F, Weightman WM, Hocking G: Patient perceptions of regional anesthesia: Influence of gender, recent anesthesia experience, and perioperative concerns. *Reg Anesth Pain Med* 2011; 36:332–5
35. Oldman M, McCartney CJ, Leung A, Rawson R, Perlas A, Gadsden J, Chan VW: A survey of orthopedic surgeons' attitudes and knowledge regarding regional anesthesia. *Anesth Analg* 2004; 98:1486–90
36. Johnson D, Truman C: Hospital practice more than specialty influences the choice of regional or general anesthesia for Cesarean section. *Can J Anaesth* 2002; 49:954–8
37. Haider AH, Schneider EB, Sriram N, Dossick DS, Scott VK, Swoboda SM, Losonczy L, Haut ER, Efron DT, Pronovost PJ,

Freischlag JA, Lipsett PA, Cornwell EE III, MacKenzie EJ, Cooper LA: Unconscious race and class bias: Its association with decision making by trauma and acute care surgeons. *J Trauma Acute Care Surg* 2014; 77:409–16

38. Chapman EN, Kaatz A, Carnes M: Physicians and implicit bias: How doctors may unwittingly perpetuate health care disparities. *J Gen Intern Med* 2013; 28:1504–10

Appendix 1. Study flow chart.



Appendix 2. Deyo–Charlson Comorbidities by Use of Neuraxial Anesthesia and Peripheral Nerve Block

	Use of Neuraxial Anesthesia			Use of Peripheral Nerve Block		
	Yes (n = 236,083), n (%)	No (n = 826,069), n (%)	P Value*	Yes (n = 189,732), n (%)	No (n = 872,420), n (%)	P Value*
Mean Deyo–Charlson comorbidity index†	0.43 (0.89)	0.43 (0.90)	0.304	0.42 (0.88)	0.44 (0.90)	0.003
Deyo–Charlson comorbidity grouping						
Myocardial infarction	10,476 (4.4)	34,117 (4.1)	< 0.0001	8,057 (4.2)	36,536 (4.2)	0.249
Congestive heart failure	8,931 (3.8)	30,088 (3.6)	0.001	7,016 (3.7)	32,003 (3.7)	0.535
Peripheral vascular disease	6,698 (2.8)	21,470 (2.6)	< 0.0001	4,998 (2.6)	23,170 (2.7)	0.596
Cerebrovascular disease	3,629 (1.5)	11,711 (1.4)	< 0.0001	2,768 (1.5)	12,572 (1.4)	0.555
Dementia	818 (0.3)	2,419 (0.3)	< 0.0001	557 (0.3)	2,680 (0.3)	0.329
Chronic pulmonary disease	39,209 (16.6)	135,107 (16.4)	0.003	30,641 (16.1)	143,675 (16.5)	0.001
Rheumatologic disease	10,551 (4.5)	37,615 (4.6)	0.083	8,366 (4.4)	39,800 (4.6)	0.004
Peptic ulcer disease	2,852 (1.2)	9,948 (1.2)	0.882	2,274 (1.2)	10,526 (1.2)	0.772
Mild liver disease	2,651 (1.1)	10,596 (1.3)	< 0.0001	2,113 (1.1)	11,134 (1.3)	< 0.0001
Moderate/severe liver disease	195 (0.1)	1,002 (0.1)	< 0.0001	172 (0.1)	1,025 (0.1)	0.002
Diabetes	44,618 (18.9)	157,931 (19.1)	0.017	38,101 (20.1)	164,448 (18.8)	< 0.0001
Diabetes with chronic complications	3,600 (1.5)	12,054 (1.5)	0.020	2,959 (1.6)	12,695 (1.5)	0.001
Hemiplegia or paraplegia	289 (0.1)	1,535 (0.2)	< 0.0001	290 (0.2)	1,534 (0.2)	0.028
Renal disease	11,403 (4.8)	38,725 (4.7)	0.004	9,041 (4.8)	41,087 (4.7)	0.301
Any malignancy	4,290 (1.8)	13,825 (1.7)	< 0.0001	3,270 (1.7)	14,845 (1.7)	0.504
Metastatic solid tumor	471 (0.2)	1,844 (0.2)	0.029	359 (0.2)	1,956 (0.2)	0.003
AIDS	83 (0)	483 (0.1)	< 0.0001	52 (0)	514 (0.1)	< 0.0001

* Chi-square test for categorical variables, t test for continuous variables. † Continuous variable are represented as mean (SD) instead of N (%).

AIDS = acquired immunodeficiency syndrome.

Appendix 3. Study Variables by Use of Neuraxial Anesthesia, Total Hip Arthroplasty Patients

	Use of Neuraxial Anesthesia		%	P Value*
	Yes (n = 71,158), N	No (n = 271,568), N		
Patient related				
Age (yr)				
< 45	3,055	14,486	17.4	< 0.0001
45–54	9,796	41,512	19.1	
55–64	19,318	75,428	20.4	
65–74	21,219	78,402	21.3	
75–99	17,770	61,740	22.4	
Gender				
Female	39,961	151,170	20.9	0.01854
Male	31,197	120,398	20.6	
Race				
White	56,037	208,426	21.2	< 0.0001
Black	3,545	19,468	15.4	
Hispanic	800	2,332	25.5	
Other	10,776	41,342	20.7	
Mean Deyo–Charlson comorbidity index†	0.43 (0.92)	0.43 (0.94)	—	0.1905

(Continued)

Appendix 3. (Continued)

	Use of Neuraxial Anesthesia			P Value*
	Yes (n = 71,158), N	No (n = 271,568), N	%	
Healthcare related				
Insurance type				
Commercial	28,205	113,314	19.9	< 0.0001
Medicaid	1,616	8,737	15.6	
Medicare	38,788	140,255	21.7	
Uninsured	591	2,280	20.6	
Other	1,958	6,982	21.9	
Hospital location				
Urban	60,352	245,915	19.7	< 0.0001
Rural	10,806	25,653	29.6	
Hospital size				
< 300 beds	25,290	95,451	21.0	< 0.0001
300–499 beds	29,486	94,781	23.7	
≥ 500 beds	16,382	81,336	16.8	
Hospital teaching status				
Nonteaching	51,194	144,468	26.2	< 0.0001
Teaching	19,964	127,100	13.6	
Procedure related				
Use of general anesthesia				
Yes	37,756	203,510	15.6	< 0.0001
No	33,402	68,058	32.9	
Use of peripheral nerve block				
Yes	8,663	22,366	27.9	< 0.0001
No	62,495	249,202	20.0	
Use of anticoagulants				
None	3,820	16,753	18.6	< 0.0001
Antiplatelets: aspirin	2,936	18,599	13.6	
Anticoagulants: warfarin	18,417	71,786	20.4	
Anticoagulants: heparin	17,944	71,787	20.0	
Anticoagulants: other	7,386	26,298	21.9	
> 1 of above	20,655	66,345	23.7	
Year of procedure				
2006	6,941	25,509	21.4	< 0.0001
2007	7,258	27,100	21.1	
2008	7,286	28,338	20.5	
2009	9,323	33,004	22.0	
2010	10,693	35,962	22.9	
2011	10,446	38,960	21.1	
2012	9,970	42,135	19.1	
2013	9,241	40,560	18.6	

* Chi-square test for categorical variables, *t* test for continuous variables. † Continuous variable are represented as mean (SD) instead of N (%).

Appendix 4. Study Variables by Use of Peripheral Nerve Block, Total Hip Arthroplasty Patients

	Use of Peripheral Nerve Block		%	P Value*
	Yes (n = 31,029), N	No (n = 311,697), N		
Patient related				
Age (yr)				
< 45	1,287	16,254	7.3	< 0.0001
45–54	4,275	47,033	8.3	
55–64	8,892	85,854	9.4	
65–74	9,130	90,491	9.2	
75–99	7,445	72,065	9.4	
Gender				
Female	17,268	173,863	9.0	0.66426
Male	13,761	137,834	9.1	
Race				
White	25,565	238,898	9.7	< 0.0001
Black	1,475	21,538	6.4	
Hispanic	189	2,943	6.0	
Other	3,800	48,318	7.3	
Mean Deyo–Charlson comorbidity index†	0.41 (0.91)	0.43 (0.94)	—	< 0.0001
Healthcare related				
Insurance type				
Commercial	13,237	128,282	9.4	< 0.0001
Medicaid	700	9,653	6.8	
Medicare	16,244	162,799	9.1	
Uninsured	191	2,680	6.7	
Other	657	8,283	7.4	
Hospital location				
Urban	27,829	278,438	9.1	0.05153
Rural	3,200	33,259	8.8	
Hospital size				
< 300 beds	8,243	112,498	6.8	< 0.0001
300–499 beds	11,538	112,729	9.3	
≥ 500 beds	11,248	86,470	11.5	
Hospital teaching status				
Nonteaching	11,937	183,725	6.1	< 0.0001
Teaching	19,092	127,972	13.0	
Procedure related				
Use of general anesthesia				
Yes	12,037	229,229	5.0	< 0.0001
No	18,992	82,468	18.7	
Use of neuraxial anesthesia				
Yes	8,663	62,495	12.2	< 0.0001
No	22,366	249,202	8.2	
Use of anticoagulants				
None	2,055	18,518	10.0	< 0.0001
Antiplatelets: aspirin	4,180	17,355	19.4	
Anticoagulants: warfarin	8,492	81,711	9.4	
Anticoagulants: heparin	5,926	83,805	6.6	
Anticoagulants: other	2,214	31,470	6.6	
> 1 of above	8,162	78,838	9.4	
Year of procedure				
2006	2,944	29,506	9.1	< 0.0001
2007	2,976	31,382	8.7	
2008	2,970	32,654	8.3	
2009	3,377	38,950	8.0	
2010	4,131	42,524	8.9	
2011	5,004	44,402	10.1	
2012	4,896	47,209	9.4	
2013	4,731	45,070	9.5	

* Chi-square test for categorical variables, t test for continuous variables. † Continuous variable are represented as mean (SD) instead of N (%).

Appendix 5. Study Variables by Use of Neuraxial Anesthesia, Total Knee Arthroplasty Patients

	Use of Neuraxial Anesthesia			P Value*
	Yes (n = 164,925), N	No (n = 554,501), N	%	
Patient related				
Age (yr)				
< 45	2,124	9,735	17.9	< 0.0001
45–54	16,575	64,064	20.6	
55–64	47,203	165,623	22.2	
65–74	58,698	191,803	23.4	
75–99	40,325	123,276	24.7	
Gender				
Female	102,968	350,782	22.7	< 0.0001
Male	61,957	203,719	23.3	
Race				
White	126,763	414,159	23.4	< 0.0001
Black	9,265	42,323	18.0	
Hispanic	2,682	8,830	23.3	
Other	26,215	89,189	22.7	
Mean Deyo–Charlson comorbidity index†	0.44 (0.88)	0.43 (0.88)	—	0.0306
Healthcare related				
Insurance type				
Commercial	58,490	204,833	22.2	< 0.0001
Medicaid	2,963	15,146	16.4	
Medicare	97,387	311,795	23.8	
Uninsured	679	2,197	23.6	
Other	5,406	20,530	20.8	
Hospital location				
Urban	135,994	494,912	21.6	< 0.0001
Rural	28,931	59,589	32.7	
Hospital size				
< 300 beds	60,388	206,339	22.6	< 0.0001
300–499 beds	72,801	193,601	27.3	
≥ 500 beds	31,736	154,561	17.0	
Hospital teaching status				
Nonteaching	120,229	324,507	27.0	< 0.0001
Teaching	44,696	229,994	16.3	
Procedure related				
Use of general anesthesia				
Yes	83,027	410,986	16.8	< 0.0001
No	81,898	143,515	36.3	
Use of peripheral nerve block				
Yes	42,972	115,731	27.1	< 0.0001
No	121,953	438,770	21.75	
Use of anticoagulants				
None	8,747	36,966	19.1	< 0.0001
Antiplatelets: aspirin	7,973	39,101	16.9	
Anticoagulants: warfarin	45,973	142,698	24.4	
Anticoagulants: heparin	42,206	150,262	21.9	
Anticoagulants: other	15,862	61,696	20.5	
> 1 of above	44,164	123,778	26.3	
Year of procedure				
2006	17,145	52,366	24.7	< 0.0001
2007	18,153	57,009	24.2	
2008	18,549	60,577	23.4	
2009	21,267	67,777	23.9	
2010	24,533	74,663	24.7	
2011	23,734	79,883	22.9	
2012	21,653	83,165	20.7	
2013	19,891	79,061	20.1	

* Chi-square test for categorical variables, *t* test for continuous variables. † Continuous variable are represented as mean (SD) instead of N (%).

Appendix 6. Study Variables by Use of Peripheral Nerve Block, Total Knee Arthroplasty Patients

	Use of Peripheral Nerve Block			
	Yes (n = 158,703), N	No (n = 560,723), N	%	P Value*
Patient related				
Age (yr)				
< 45	2,320	9,539	19.6	< 0.0001
45–54	16,973	63,666	21.1	
55–64	47,055	165,771	22.1	
65–74	56,629	193,872	22.6	
75–99	35,726	127,875	21.8	
Gender				
Female	99,384	354,366	21.9	< 0.0001
Male	59,319	206,357	22.3	
Race				
White	127,834	413,088	23.6	< 0.0001
Black	10,692	40,896	20.7	
Hispanic	2,105	9,407	18.3	
Other	18,072	97,332	15.7	
Mean Deyo–Charlson comorbidity index†	0.43 (0.87)	0.44 (0.88)	—	0.001
Healthcare related				
Insurance type				
Commercial	58,697	204,626	22.3	< 0.0001
Medicaid	3,317	14,792	18.3	
Medicare	90,909	318,273	22.2	
Uninsured	497	2,379	17.3	
Other	5,283	20,653	20.4	
Hospital location				
Urban	139,632	491,274	22.1	< 0.0001
Rural	19,071	69,449	21.5	
Hospital size				
< 300 beds	44,505	222,222	16.7	< 0.0001
300–499 beds	61,702	204,700	23.2	
≥ 500 beds	52,496	133,801	28.2	
Hospital teaching status				
Nonteaching	96,283	348,453	21.7	< 0.0001
Teaching	62,420	212,270	22.7	
Procedure related				
Use of general anesthesia				
Yes	99,611	394,402	20.2	< 0.0001
No	59,092	166,321	26.2	
Use of neuraxial anesthesia				
Yes	42,972	121,953	26.1	< 0.0001
No	115,731	438,770	20.9	
Use of anticoagulants				
None	9,027	36,686	19.7	< 0.0001
Antiplatelets: aspirin	8,626	38,448	18.3	
Anticoagulants: warfarin	39,122	149,549	20.7	
Anticoagulants: heparin	38,300	154,168	19.9	
Anticoagulants: other	20,704	56,854	26.7	
> 1 of above	42,924	125,018	25.6	
Year of procedure				
2006	10,600	58,911	15.3	< 0.0001
2007	12,447	62,715	16.6	
2008	14,257	64,869	18.0	
2009	18,944	70,100	21.3	
2010	24,747	74,449	25.0	
2011	26,442	77,175	25.5	
2012	27,009	77,809	25.8	
2013	24,257	74,695	24.5	

* Chi-square test for categorical variables, *t* test for continuous variables. † Continuous variable are represented as mean (SD) instead of N (%).

Appendix 7. Multilevel Multivariable Model Depicting Variables for the Composite Outcome of Either the Use of Neuraxial Anesthesia or Peripheral Nerve Block

	OR*	95% CI		P Value
Age (continuous)	1.07	1.06	1.08	< 0.0001
Race (reference: white)				
Black	0.90	0.88	0.92	< 0.0001
Hispanic	0.76	0.72	0.81	< 0.0001
Other	1.09	1.06	1.11	< 0.0001
Insurance type (reference: commercial)				
Medicaid	0.80	0.77	0.83	< 0.0001
Medicare	0.92	0.90	0.93	< 0.0001
Uninsured	0.84	0.77	0.91	< 0.0001
Other	1.03	1.00	1.07	0.0574
Hospital location (reference: urban)				
Rural	1.08	0.48	2.44	0.8538
Hospital teaching status (reference: nonteaching)				
Teaching	0.53	0.25	1.12	0.0954

* Adjusted for gender, use of general anesthesia, year of procedure, type of procedure, hospital size, chronic pulmonary disease, rheumatologic disease, peptic ulcer disease, mild liver disease, moderate/severe liver disease, diabetes, diabetes with chronic complications, hemiplegia or paraplegia, renal disease, any malignancy, metastatic solid tumor, AIDS.

AIDS = acquired immunodeficiency syndrome; OR = odds ratio.

Appendix 8. Multilevel Multivariable Model Depicting Variables for Both Use of Neuraxial Anesthesia (Left) and Use of Peripheral Nerve Block (Right); Cohort Restricted to Patients with Known Type of Anesthesia

	Outcome: Use of Neuraxial Anesthesia				Outcome: Use of Peripheral Nerve Block			
	OR*	95% CI		P Value	OR†	95% CI		P-value
Age (continuous)	1.04	1.03	1.05	< 0.0001	1.05	1.04	1.06	< 0.0001
Race (reference: white)								
Black	0.82	0.79	0.85	< 0.0001	0.96	0.92	0.99	0.0089
Hispanic	0.49	0.44	0.54	< 0.0001	0.66	0.61	0.72	< 0.0001
Other	0.95	0.92	0.98	0.0010	0.93	0.90	0.96	< 0.0001
Insurance type (reference: commercial)								
Medicaid	0.76	0.72	0.81	< 0.0001	0.90	0.84	0.95	0.0003
Medicare	0.98	0.96	1.01	0.1176	0.92	0.90	0.94	< 0.0001
Uninsured	0.74	0.65	0.84	< 0.0001	0.91	0.80	1.04	0.1626
Other	0.98	0.94	1.03	0.4624	0.98	0.93	1.03	0.3761
Hospital location (reference: urban)								
Rural	1.69	1.09	2.62	0.0183	1.53	0.46	5.96	0.4887
Hospital teaching status (reference: nonteaching)								
Teaching	0.57	0.38	0.85	0.0062	1.10	0.37	3.28	0.8685

* Adjusted for gender, use of general anesthesia, year of procedure, type of procedure, hospital size, myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, rheumatologic disease, mild liver disease, moderate/severe liver disease, diabetes, diabetes with chronic complications, hemiplegia or paraplegia, renal disease, any malignancy, metastatic solid tumor, and AIDS. † Adjusted for gender, use of general anesthesia, year of procedure, type of procedure, hospital size, chronic pulmonary disease, rheumatologic disease, peptic ulcer disease, mild liver disease, moderate/severe liver disease, diabetes, diabetes with chronic complications, hemiplegia or paraplegia, renal disease, any malignancy, metastatic solid tumor, and AIDS.

AIDS = acquired immunodeficiency syndrome; OR = odds ratio.