Retrospective Study

Racial and Ethnic Disparities in Inpatient Interventional Pain Management for Lumbar Radiculopathy

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Disclaimer: We would like to thank the Emory School of Medicine and the Department of Anesthesiology at Emory for their generous support to conduct this research project. There was no external funding in the preparation of this manuscript.

Conflict of interest: Vinita Singh, MD: Consultant Releviate, LLC – 2020-2021. All other authors certify that he or she, or a member of his or her immediate family, have no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted manuscript.

Manuscript received: 08-22-2022
Revised manuscript received: 02-23-2023
Accepted for publication: 03-28-2023

Free full manuscript: www.painphysicianjournal.com

Background: Chronic pain is a common reason adults seek care; patients often feel that their pain is inadequately managed. Spine-related pain is the most common chronic pain concern, and lumbar radiculopathy is often the cause. Racial and ethnic disparities in the pharmacologic management of pain are well described, but less is known about these disparities regarding interventional procedures.

Objective: To study the utilization rates of physical therapy, epidural steroid injection, surgery, and spinal cord stimulation in hospitalized patients with lumbar radiculopathy across different races, ethnicities, and genders.

Study Design: A retrospective cross-sectional study design.

Methods: The National Inpatient Sample was used to identify 252,790 patients with lumbar radiculopathy, after sample weighting, from 2016-2019. Independent variables were race, ethnicity, age, gender, insurance, geography, year, and severity. Dependent variables were physical therapy, epidural steroid injection, spinal cord stimulator, or surgery (reference group). Conservative management was defined as nonoperative treatment ranging from physical therapy to epidural steroid injection. Data were analyzed with a logistic regression for complex surveys. Regressions were adjusted for age, insurance, geography, and other socioeconomic factors.

Results: Most patients were white (78.3%) and received surgery (95.0%). Severe disease was most common among African Americans (9.3%), but was similar across other races, ethnicities, and genders. Medicaid was more common among African Americans and Hispanics. An adjusted analysis showed that African Americans and Hispanics received more epidural steroid injections (odds ratio [OR] = 1.52; 95%CI, 1.3 – 1.8) and (OR = 1.43; 95%CI, 1.1 – 1.8) respectively; and physical therapy (OR = 1.65; 95%CI, 1.1 – 2.5) and (OR = 1.83; 95%CI, 1.2 – 2.8) respectively, than whites compared to surgery. African Americans received a spinal cord stimulator less often than whites compared to surgery (OR = 0.63; 95%CI. 0.4 – 0.9). Women received an epidural steroid injection more frequently than men compared to surgery (OR = 1.29; 95%CI, 1.2 – 1.4).

Limitations: Generalizability is limited because conservative therapies are often outpatient treatments.

Conclusion: Disparities were observed in lumbar radiculopathy treatment after independent variable adjustment. African Americans received conservative therapy more often than whites despite increased disease severity. Hispanics and women had similar disease severity compared to whites and men, respectively, but received more conservative therapies. Further investigation in outpatient settings is needed to definitively describe these disparities.

Key words: Chronic pain, pain management, back pain, lumbar radiculopathy, epidural steroid injection, spinal cord stimulation, low back surgery, physical therapy, racial disparities, gender disparities

Pain Physician 2023: 26:E517-E527

Chronic pain is a common reason adults seek care, afflicting 43% of adults in the United States (1). Unfortunately, 39% of patients feel their pain is inadequately managed (1). Spine-related pain is the most common chronic pain disorder; lumbar radiculopathy is often the cause (2,3). Common therapies for lumbar radiculopathy include physical therapy (PT), epidural steroid injection (ESI), surgery, or spinal cord stimulator (SCS) (3,4).

Conservative and nonoperative therapy is defined as nonoperative treatment ranging from PT to ESI (5). PT improves physical functioning and is considered a mainstay of multidisciplinary pain management (4). ESI meta-analyses have demonstrated that the number needed to treat is 3 patients to achieve at least 50% pain relief compared to placebo (6).

Advanced therapy, such as surgery and SCS, are used when conservative management fails (5,7). Surgical outcomes improve when radiological findings correlate with clinical concerns in patients who have failed 6-8 weeks of conservative management (5). Systematic reviews show that SCS can reduce pain and improve quality of life (7). Given the effectiveness of these therapeutic procedures, it is beneficial to understand disparities in their utilization.

Studies have shown existing disparities in pharmaceutical pain management. Racial and ethnic minorities receive lower-quality care than white patients after adjusting for access-related factors, needs, preferences, and appropriateness of interventions (8). For example, African American patients are less likely to receive analgesia for nontraumatic/nonsurgical pain, and are more likely to have their pain underestimated (9). Also, African American and Hispanic patients are less likely than white patients to receive opioids for back pain (8). Hispanic patients frequently have shorter clinic visits to address their back pain compared to white non-Hispanic patients (8). These are critical issues, especially since minorities experience a higher prevalence of pain and pain-related disabilities (10).

Our aim was to determine the likelihood of conservative therapy – PT or ESI – versus advanced therapy – SCS or surgery – in patients who were hospitalized with lumbar radiculopathy across different races, ethnicities, and genders.

Study Design and Methods

Database Characteristics

A retrospective, cross-sectional study design utilized data from the Healthcare Cost and Utilization Project (HCUP), which is sponsored by the Agency for Healthcare Research and Quality (11). It is the largest collection of longitudinal hospital care data in the United States. Within HCUP, we reviewed the National Inpatient Sample (NIS) from 2016 through 2019. The NIS includes discharge-level data from more than 7 million community hospitals in the United States, excluding rehabilitation and long-term acute care hospitals.

The NIS includes a core set of clinical and nonclinical data. We analyzed International Classification of Diseases, Tenth Revision codes (ICD-10) and ICD-10, Procedure Coding System codes (ICD-10-PCS), patient demographics, total charges, and insurance status (Medicare, Medicaid, private insurance, self-pay, no pay, and "other" – social, local, state, and federal government policies). The NIS includes data regardless of payer. ICD-10 and ICD-10-PCS codes were assigned by the treating clinicians or hospital departments. The NIS hospital regional data follow the US Census Bureau definitions (see Supplemental Fig. 1). The NIS population density data follow the National Center for Health Statistics (see supplemental variable definitions). Urban and suburban counties have populations of at least one million, with urban defined as the "Central" counties and suburban the surrounding "Fringe" counties. The NIS ZIP code income quartile data (median household income for a patient's ZIP code divided into quartiles) were obtained from Claritas (see supplemental variable definitions).

The NIS has frequently been used to make national estimates of health care utilization. It is publicly available, deidentified (personal data are redacted), and is a limited sample. An institutional review board waiver was obtained prior to any data mining.

Inpatient data made all treatments readily available. PT, ESI, and SCS are typically outpatient procedures, but can also be completed as an inpatient. Conversely, spine surgeries require inpatient admission and postoperative monitoring; they cannot be completed in an outpatient setting. Therefore, with the NIS, all treatment outcomes of all patients are available. Moreover, selecting inpatient data captures more severe and symptomatic pain. The study cohort is more likely to have indications for and access to the full range of treatments compared to patients receiving outpatient care; thus, more clinical decision making is required to determine the appropriate treatment choice, with more opportunities to introduce biases across a broader range of treatment options.

Exclusion Criteria

Exclusion criteria are summarized in Fig. 1. We excluded records without Major Diagnostic Category (MDC) of Diseases and Disorders of the Nervous system (01), Disease and Disorders of the Musculoskeletal System and Connective Tissue (08), or Factors Influencing Health Status and Other Contacts with Health Services (23). Records without ICD-10 codes for lumbar radiculopathy (M5416 and M5417), sacral radiculopathy (M5418), sciatica (M5431 and M5432), or lumbago with sciatica (M5441 and M5442) were then excluded. We also excluded records without the Diagnosis Related Group (DRG) of spinal procedures (028-030), spinal disorders and injuries (052-053), spinal fusion (453-460), other musculo-

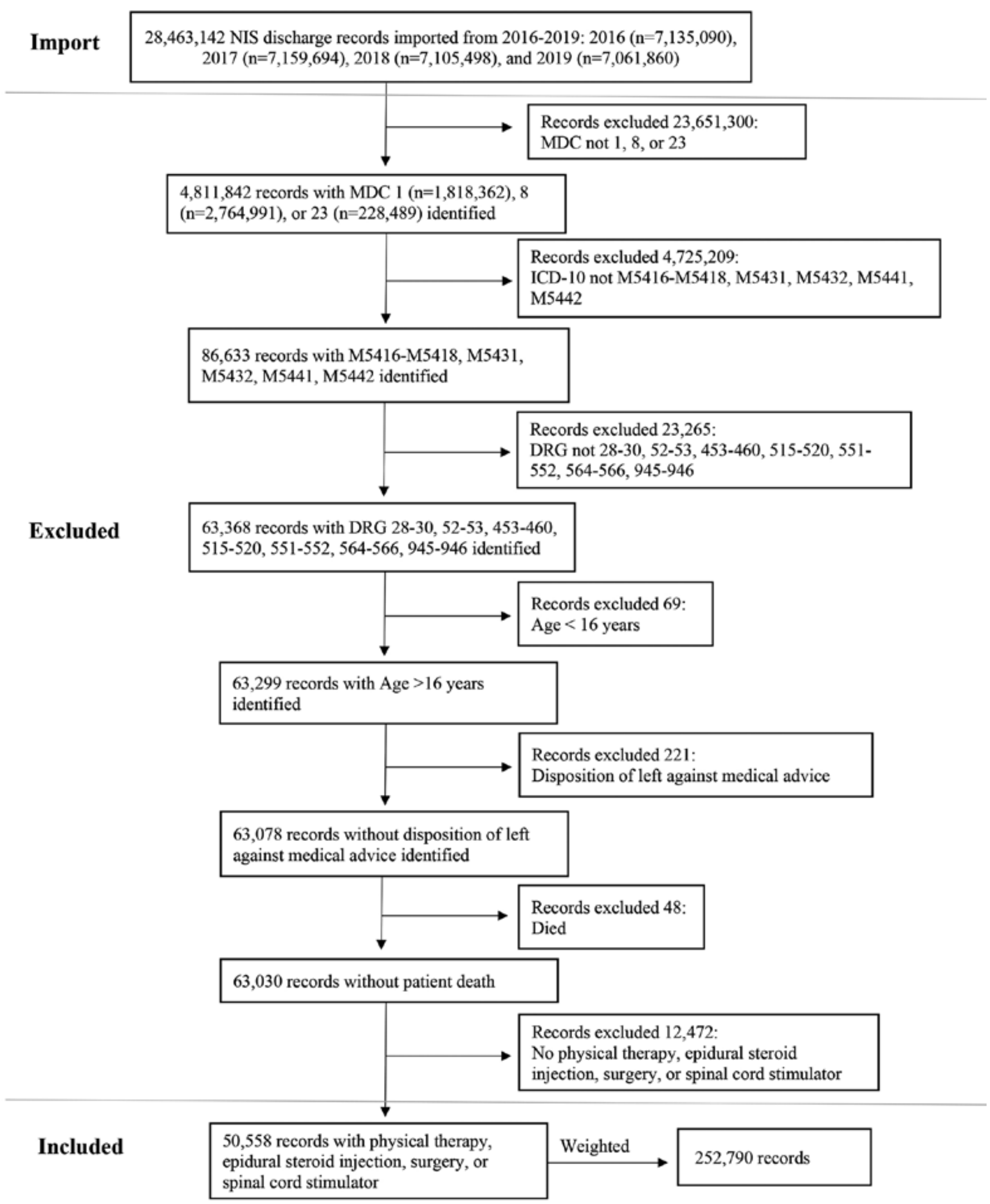

Fig. 1. *Exclusion criteria flow chart.*

skeletal and connective tissue procedures (515-517), back and neck procedures except for spinal fusion or neurostimulation (518-520), medical back problems (551-552), other musculoskeletal and connective tissue diagnoses (564-566) and rehabilitation (945-946). We chose these to ensure analyzed patients were admitted for pain secondary to lumbar radiculopathy and not a concomitant comorbidity. Age less than 16 years was excluded since lumbar radiculopathy is typically caused by degenerative changes. Records with a discharge disposition of "Against Medical Advice" (AMA) and records indicating patient death were excluded since receiving treatment for lumbar radiculopathy was our primary outcome. Records without ICD-10-PCS codes pertaining to PT, ESI, SCS, or surgery were then excluded. This limited our patient population to those with pain necessitating treatment. Discharge records were weighted per HCUP requirements to produce national estimates of all patient discharges (12).

Independent and Dependent Variables

Dependent variables were PT, ESI, SCS, or surgery. The HCUP Clinical Classification Software Refined (US Agency for Healthcare Research and Quality) was used to determine which treatment category ICD-10-PCS codes belonged to (see supplemental ICD-10/PCS codes).

Due to the large sample size discrepancies between procedure groups, the largest category, surgery, was used as a reference group. If a patient had ICD-10-PCS codes that fit 2 or more treatment categories, a categorizing hierarchy was followed: ESI > SCS > surgery > PT. For instance, a patient who had both surgery and PT was placed in the surgery group. This hierarchy allowed for treating the outcome as a single variable, reducing the risk of false positives. An overlap significant enough to affect odds ratios was only observed with PT and surgery (18.0%), ESI and surgery (10.9%), and SCS and Surgery (23.5%) (see Supplemental Tables 1 and 2 for further explanation).

ESI and SCS were selected before surgery in the hierarchy, thus, their outcomes are not affected by the overlap. Surgery was selected before PT in the hierarchy, however PT is a routine adjunct to surgery and part of the postoperative recovery process. Therefore, PT is the primary treatment only when administered for pain relief in the absence of a surgical intervention.

Independent variables included race and ethnicity (white, African American, Hispanic, other/unknown), age, gender, insurance status, ZIP code income quartile, population density, hospital region, year, and All Patient Refined Diagnosis Related Group (APR-DRG) severity. All independent variables, except year, were adjusted for to minimize the effects of socioeconomic factors on race and ethnicity outcomes. The NIS records race and ethnicity as a single variable, with Hispanic taking priority over any race. Asian or Pacific Islanders and Native Americans were combined with "other" and "unknown" for analysis.

APR-DRG severity was developed by 3M Health Information Systems (13). This is a DRG-based measurement system that determines the severity subclass of illness. Subclass is numbered one to 4 indicating, respectively, minor, moderate, major, or extreme loss of function. Subclasses are assigned using a 3-phase process. First, severity is assigned to each secondary diagnosis. Second, an initial subclass is assigned based off the secondary diagnosis severity. Third, the severity of illness subclass is modified by determining interactions among the principal diagnosis, age, procedures (nonsurgical and surgical), and all secondary diagnoses. Clinical expectations developed through this system were tested against historical data from national databases.

Statistical Analyses

The statistical analysis was performed using SAS 9.4 software (SAS Institute) procedures for complex survey data (14). For all analyses, data were stratified by hospital division (n = 196), clustered by hospital (n = 6,320) and weighted by individual patient (average weight: 5.0) per HCUP requirements. The Rao-Scott χ^2 test was used for independent variable comparisons by race and ethnicity (15). Logistic regression was conducted for outcomes. Data were imputed using the Bayesian bootstrap hot-deck method with 5 donors, if the variable was missing less than 1,000 data points, for adjusted logistic regression models (16). The weighting was reduced from 5 to one for these observations to rebalance the weighted frequency. Stepwise selection (forward entry $P < 0.05$, removal $P > 0.15$) was used for choosing significant independent variables in the logistic regression models.

Results

Lumbar Radiculopathy Demographics and Treatment

Variables by race/ethnicity and gender are summarized in Table 1 and Fig. 2, respectively. We identified 252,790 patients hospitalized with lumbar radiculopathy from 2016 through 2019. The largest group was age 65 and older. Women were 54.6% of the cohort. Most patients were white (78.3%). The other/unknown race group was 7.5% of the total sample and consisted of 18.6% Asian or Pacific Islanders, 5.9% Native Americans, 31.2% other, and 44.2% unknown.

Urban hospital admissions rates were highest among African American (40.8%) and Hispanic (43.1%)

Table 1. *Variable and procedure distribution by race/ethnicity.*

Variable		Race and Ethnicity					*P* Value[a]
		White	African American	Hispanic	Other/ Unknown	Total	
Weighted Total, n (%)		197,955 (78.3)	19,605 (7.8)	16,285 (6.4)	18,945 (7.5)	252,790	
Gender, n (%)	Men	91,285 (46.1)	7,410 (37.8)	7,545 (46.3)	8,605 (45.4)	114,845 (45.4)	< 0.001
	Women	106,650 (53.9)	12,195 (62.2)	8,740 (53.7)	10,340 (54.6)	137,925 (54.6)	
Age in years, n (%)	16-25	1,125 (0.6)	60 (0.3)	215 (1.3)	255 (1.3)	1,655 (0.7)	< 0.001
	26-44	15,215 (7.7)	1,755 (9.0)	2,445 (15.0)	1,840 (9.7)	21,255 (8.4)	
	45-64	78,810 (39.8)	10,935 (55.8)	7,745 (47.6)	8,055 (42.5)	105,545 (41.8)	
	65 and up	102,805 (51.9)	6,855 (35.0)	5,580 (36.1)	8,795 (46.4)	124,335 (49.2)	
Length of Stay (days)	Median (IQR)	2.3 (1.2, 3.6)	2.6 (1.5, 4.6)	2.4 (1.4, 4.0)	2.3 (1.3, 3.6)	2.3 (1.3, 3.7)	< 0.001
	Mean (SD)	3.4 (0.02)	4.2 (0.1)	3.8 (0.06)	3.5 (0.05)	3.5 (0.02)	
Hospital Region, n (%)	Northeast	31,415 (15.9)	2,995 (15.2)	2,600 (16.0)	2,755 (14.5)	39,765 (15.8)	< 0.001
	Midwest	47,465 (24.0)	3,520 (18.0)	1,450 (8.9)	4,755 (25.1)	57,190 (22.6)	
	South	79,790 (40.3)	11,210 (57.2)	6,935 (42.6)	5,365 (28.3)	103,300 (40.9)	
	West	39,285 (19.8)	1,880 (9.6)	5,300 (32.5)	6,070 (32.0)	52,535 (20.8)	
Population Density, n (%)[b]	Urban	39,525 (20.0)	8,000 (40.8)	7,020 (43.1)	5,530 (29.2)	60,075 (23.8)	< 0.001
	Suburban	53,655 (27.1)	4,065 (20.7)	3,350 (20.6)	4,290 (22.6)	65,900 (26.1)	
	Medium[c]	43,570 (22.0)	3,630 (18.5)	3,525 (21.6)	3,715 (19.6)	54,440 (21.5)	
	Small[d]	22,785 (11.5)	1,555 (7.9)	1,000 (6.1)	1,945 (10.3)	27,285 (10.8)	
	Rural	38,240 (19.3)	1,770 (9.0)	1,320 (8.1)	3,435 (18.1)	44,765 (17.7)	
ZIP Code Income Quartile, n (%)[b, e]	0-25th	39,165 (19.8)	8,410 (42.9)	5,250 (32.2)	3,515 (18.6)	56,340 (22.3)	< 0.001
	26-50	52,205 (26.4)	4,300 (21.9)	4,045 (24.8)	4,675 (24.7)	65,225 (25.8)	
	51-75	53,160 (26.9)	3,935 (20.1)	3,915 (24.0)	4,845 (25.6)	65,855 (26.1)	
	76-100	50,615 (25.6)	2,680 (13.7)	2,810 (17.3)	5,530 (29.2)	61,635 (24.4)	
Insurance, n (%)[b]	Medicare	105,520 (53.3)	8,665 (44.2)	6,505 (39.9)	8,850 (46.7)	129,540 (51.2)	< 0.001
	Private	69,945 (35.3)	6,470 (33.0)	5,555 (34.1)	6,970 (36.8)	88,940 (35.2)	
	Medicaid	10,025 (5.1)	2,310 (11.8)	2,045 (12.6)	1,465 (7.7)	15,845 (6.3)	
	Self-pay	1,190 (0.6)	305 (1.6)	370 (2.3)	200 (1.1)	2,065 (0.8)	
	No Charge	75 (0.04)	45 (0.2)	35 (0.2)	25 (0.1)	180 (0.1)	
	Other	10,970 (5.5)	1,770 (9.0)	1,760 (10.8)	1,415 (7.5)	15,915 (6.3)	
Severity, n (%)[b]	Minor	77,565 (39.2)	7,095 (36.2)	6,665 (40.9)	8,140 (43.0)	99,465 (39.3)	< 0.001
	Moderate	65,420 (33.0)	6,570 (33.5)	4,855 (29.8)	6,150 (32.5)	82,995 (32.8)	
	Major	14,825 (7.5)	1,675 (8.5)	1,235 (7.6)	1,420 (7.5)	19,155 (7.6)	
	Extreme	1,275 (0.6)	160 (0.8)	100 (0.6)	130 (0.7)	1,665 (0.7)	
Procedure, n (%)	PT	1,310 (0.7)	225 (1.1)	205 (1.3)	165 (0.9)	1,905 (0.8)	< 0.001
	ESI	5,880 (3.0)	965 (4.9)	685 (4.2)	595 (3.1)	8,125 (3.2)	
	SCS	2,140 (1.1)	170 (0.9)	175 (1.1)	170 (0.9)	2,655 (1.0)	
	Surgery	188,625 (95.3)	18,245 (93.1)	15,220 (93.5)	18,015 (95.1)	240,105 (95.0)	

[a] Rao-Scott χ^2 test was used to compare proportions, Length of Stay was grouped as 0-2,3, 4+ days; [b] Variable does not add to 100% because of records missing data; [c] Medium is medium metropolitan counties of less than one million; [d] Small is small metropolitan counties of less than 250,000 [e] ZIP Code Income Quartile reference amounts in dollars are listed in the supplemental file; Abbreviations: PT, physical therapy; ESI, epidural steroid injections; SCS, spinal cord stimulator; SD, standard deviation; IQR, interquartile range

patients. Insurance coverage was mostly through Medicare (51.2%). Medicaid was more common among African American (11.8%) or Hispanic (12.6%) patients compared to the total population (6.3%). Private insurance was least common among African American patients (33.0%). Major-extreme severity was most common among African American patients (9.3%), but similar when comparing women (8.5%) and men (8.0%). Surgery was the most common intervention (95.0%).

Fig. 2. *Variable and procedure distribution by gender.*
Each variable is listed as a percentage of the entire study sample by gender. Numerical values are reported in parentheses. Total represents the percentage of women and men in the study. It is used as a reference group to compare each variable to, with the dashed line representing the total percentage of women (the reference point). All groups were statistically different ($P < 0.0001$, Rao-Scott χ^2 test) except for population density ($P = 0.086$). Medium population density is medium metropolitan counties of less than 1,000,000. Small population density is small metropolitan counties of less than 250,000. ZIP Code Median Income Quartile reference amount in dollars is listed in the supplemental file. Abbreviations: PT, physical therapy;ESI, epidural steroid injection; SCS, spinal cord stimulator.

Adjusted Logistic Regression with Severity

The odds ratios of various procedures versus surgery are summarized in Fig. 3. Patients included in this analysis had a documented severity value. Of the 252,790 identified patients, 19.6% of the records were missing severity values and were excluded. However, odds ratios were similar whether or not this 19.6% was included (see Supplemental Table 2).

Independent variables were race and ethnicity, age, gender, population density, hospital region, ZIP code income quartile, insurance status, and severity. A logistic regression adjusting for each independent variable simultaneously was used to determine variable-procedure associations. Imputed variables included gender (n = 4), insurance status (n = 77), population density (n = 65), and ZIP code median income quartile (n = 747). Compared to white patients, African American and Hispanic patients were more likely to get PT rather than surgery, (odds ratio [OR] = 1.65; 95%CI,1.1 – 2.5) and (OR = 1.83; 95%CI, 1.2 – 2.8) respectively; and PT rather than an ESI, (OR = 1.52; 95%CI, 1.3– 1.8) and (OR = 1.43; 95% CI, 1.1 – 1.8) respectively. African American patients were less likely to get SCS than white patients, (OR = 0.63; 95%CI, 0.4 – 0.9). Women had higher odds of receiving an ESI than men, (OR = 1.29; 95%CI, 1.2 – 1.4). Urban hospitalized patients were less likely to undergo surgery than all other population densities. Medicaid-insured patients had higher odds of receiving an ESI, (OR = 1.89; 95%CI, 1.5 – 2.3), and lower odds of receiving SCS, (OR = 0.52; 95%CI, 0.3 – 0.8), compared to Medicare-insured patients. Medicaid-insured patients were less likely to undergo surgery than privately insured patients for all procedures except SCS (not significant).

Unadjusted Logistic Analysis

Unadjusted analyses are summarized in Supplemental Table 2. The independent variables African American and Hispanic had stronger associations with PT and ESI over surgery. Independent variable woman gender had a stronger association with ESIs over surgery. The year of admission was not a significant independent variable.

AMA (Against Medical Advice) Discharge Subset Analysis

A total of 1,105 patients were discharged AMA, after weighting. In a logistic regression model adjusting

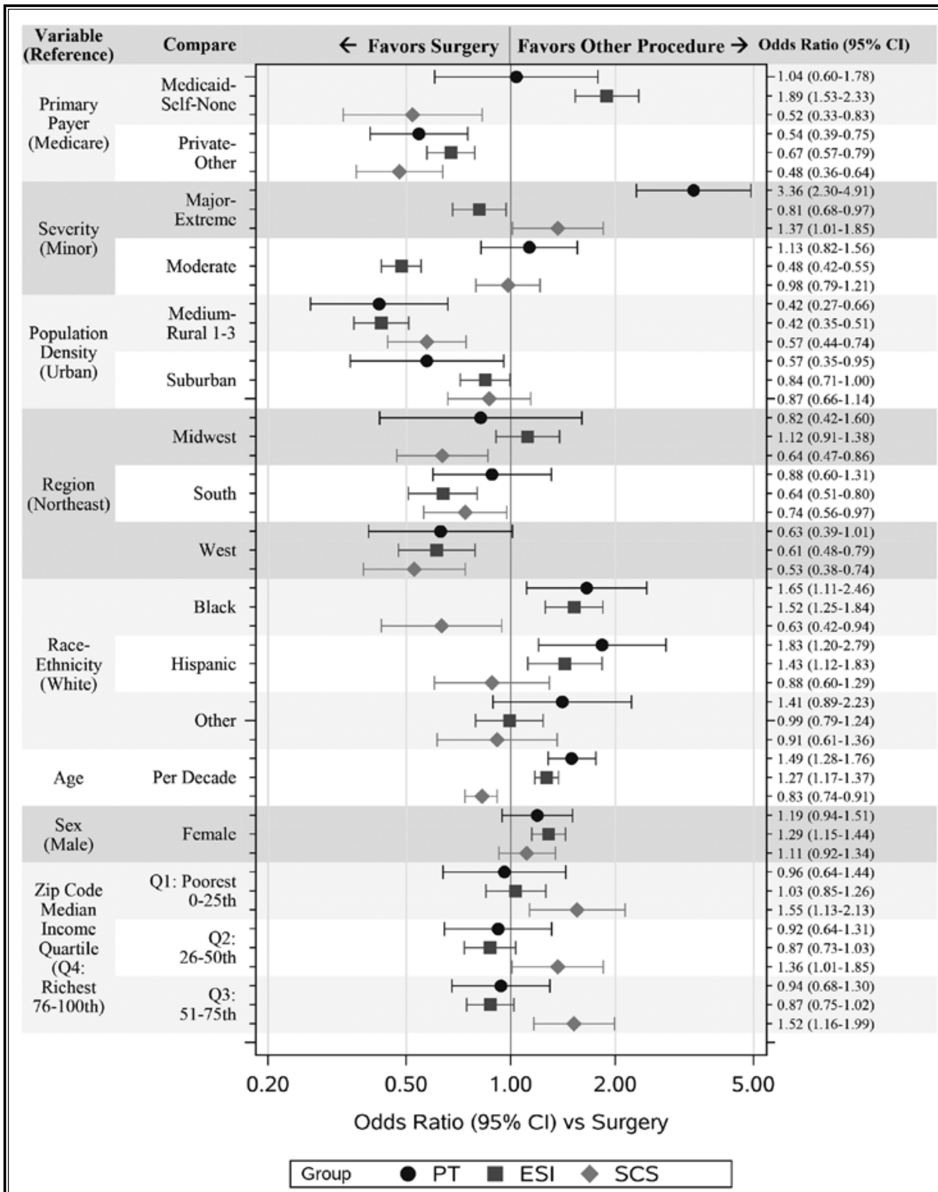

Fig. 3. ***Adjusted odds ratios for the association between type of procedure and patient factors.*** Independent variables are listed in order of strength of prediction from top to bottom. Each variable's individual odds ratio is reported in the figure after simultaneously adjusting for other independent variables. Reference groups are listed for each variable in parentheses. Surgery was used as the reference group for all procedures. Variables excluded from the model are length of stay, year, day (weekend vs weekday), surgery type (elective vs nonelective), number of diagnoses, number of procedures, and total charges. Abbreviations: 95%CI, 95% confidence interval; PT, physical therapy; ESI, epidural steroid injection; SCS, spinal cord stimulator.

for race/ethnicity and insurance status simultaneously, those who were discharged AMA were significantly more likely to be African American, (OR = 2.47; 95% CI, 1.7 – 3.6), or Hispanic, (OR = 1.93; 95%CI, 1.2 – 3.0), compared to whites who were left in the main analysis. The other/unknown race group was not statistically significantly different, (OR = 0.98; 95%CI, 0.6 – 1.7). Patients who were discharged AMA were also more likely to be on Medicaid or uninsured, (OR = 4.38; 95% CI, 3.2 – 6.1), compared to Medicare. Patients who were discharged AMA were less likely to have private insurance, (OR = 0.49; 95%CI, 0.3 – 0.7), or other insurance, (OR = 0.35; 95%CI, 0.1 – 0.9), compared to Medicare.

Discussion

African American patients in our study had the highest degree of illness severity, but were more likely to receive nonoperative treatment, PT (OR = 1.65) or an ESI (OR = 1.52), over surgery when compared to white patients. They were also less likely to receive SCS (OR = 0.63). Hispanic patients were similarly more likely to receive nonoperative treatment, PT (OR = 1.83) or ESI (OR = 1.43), despite having comparable illness severity. These were true after adjusting for age, gender, insurance type, geography, and severity. Surgery and SCS utilization should be higher among African American patients, since these are indicated with increased illness severity (3,7). Racial disparities in pharmaceutical pain management have been previously documented (8,9). Our study shows that disparities exist in interventional pain management as well.

Studies have shown that implicit biases against racial and ethnic groups are prevalent in health care (17,18). This leads to perceptions of decreased compliance and education level towards Black and Hispanic patients (17). Consequently, patient-provider interactions, treatment decisions, adherence, and outcomes are significantly affected. Patient-provider interactions and outcomes are more heavily affected than treatment processes (17). However, Sabin et al (18) demonstrated that when presented with clinical vignettes, biased providers will recommend ideal pain management less often for African American patients than white patients. Moreover, physicians have acknowledged that their self-reported racial biases could affect their treatment decisions; studies have replicated this (18,19). Therefore, implicit biases held by providers can create barriers to care and contribute to our observed racial and ethnic disparities.

Patient preferences could also help explain the racial and ethnic differences in our study. Kwoh et al (20) demonstrated that African Americans were less willing to undergo knee surgery, despite higher objective disease severity scores. Suarez-Almazor et al (21) observed that Hispanics were less willing to undergo knee surgery after controlling for severity, surgical expectations and familiarity, and trust in the physician. African American and Hispanic patients with lumbar radiculopathy in our study could have been similarly hesitant to undergo surgery. Notably, African Americans' hesitancy regarding knee surgery in the Kwoh et al study (20) decreased with improved understanding of the procedure and recovery process. Poor provider communication is an observed effect of bias against African American patients during patient-provider interactions (17). This illustrates an additional effect that biases may have on treatment utilization.

There were also discrepancies observed with patient admissions. White patients were more likely to receive advanced therapies—surgery and SCS—than African American patients, and they comprised a larger proportion of lumbar radiculopathy hospitalizations. Consistent with previous research, African American patients in our study may have sought care only when their condition became severe (20). Given that patients with severe illness made up a minority of our patient population, this could explain why fewer African American patients were hospitalized. Alternatively, providers often underestimate the pain experienced by African American patients (9,22,23). Thus, it is possible that African American patients with less severe disease presentation were not admitted due to a poor estimation of their pain levels.

Our analysis shows a significant difference in procedure utilization based on population density. Patients hospitalized in urban settings were less likely to receive surgery compared to almost all other population densities. Previous studies demonstrated similar findings with higher rates of lumbar surgery in rural locations (24). Therefore, minorities in our study may have been less likely to be offered surgery due to the hospital setting they were admitted to.

Procedure utilization in this study was affected by insurance status. Consistent with prior findings, Medicaid patients were more likely to receive conservative management over surgery (25). Medicaid plans rarely approve low back surgery and information about their coverage status is often unavailable (25). Conversely, private plans often view low back surgery as medically necessary (25). African American and Hispanic patients in our study more frequently carried Medicaid compared to white patients. This suggests that insurance coverage may contribute to racial and ethnic discrepancies in access to advanced lumbar radiculopathy treatment. Additionally, the lack of information seen in Medicaid plans may serve as a barrier to treatment (25).

Our study revealed gender differences in procedure utilization. Women were more likely to get an ESI over surgery despite being admitted with disease severity similar to men. This was true after adjusting for insurance and demographic factors. Previous studies showed that women are more likely to be undertreated for cancer and AIDS-related pain (26). The current literature suggests that women are met with disbelief during initial health care encounters and are perceived to be more tolerant of pain (26). Thus, the gender differences in this study could be due to differences in perceived pain tolerance and biases against women.

A subset analysis of patients discharged AMA excluded from our study cohort showed racial and ethnic differences. African American, Hispanic, Medicaid-insured, and uninsured patients were more likely to be discharged AMA. This may be secondary to patient preferences among African American and Hispanic patients. Both patient groups have previously demonstrated a decreased willingness to undergo surgery; one of the most common reasons for AMA discharges is procedure refusal (20,21,27). African American and Hispanic patients were also more frequently evaluated in urban, rather than rural, hospitals. It has been shown that urban hospitalization is a predictor for AMA discharge (28). The increased rates of AMA discharges may be due to decreased familiarity and trust associated with urban hospitals compared to rural and community hospitals (28). Lastly, Medicaid and uninsured payers have been found to be predictors for AMA discharge (28). This suggests that cost-related concerns increase the risk of AMA discharge (28). Our racial and ethnic differences were observed after controlling for insurance status, but this nonetheless could be a contributing factor. Patients who left AMA were not included in our main analysis.

Our study design has several strengths such as a large, representative, national sample that balances confounders and access to comprehensive health care data. Additionally, the NIS includes data regardless of payer. This is vital to our study objective since racial and ethnic minorities are more likely to have noncommercial plans or Medicaid.

However, our study is not without limitations. First, we chose to analyze inpatient data. Generalizability is limited since PT, ESI, an SCS are typically outpatient therapies. Thus, this study does not accurately depict the demographic and socioeconomic factors affecting access to outpatient interventional treatment. Second, the NIS reports only the ZIP code median income quartile rather than a patient's household income. Patients could be wealthy but living in a poorer ZIP code, making this an imperfect measure of socioeconomic status. Third, the NIS combines race and ethnicity into one variable. If a patient identifies as Hispanic, only ethnicity is reported in the NIS and race is omitted. Thus, analyses on both race and ethnicity are limited.

Finally, accounting for readmissions or pharmacological management of pain is not possible within the NIS. Patients may have previously received ESI, PT, SCS, or surgery that failed to provide symptom relief, prompting them to receive a different treatment. Also, radiographic evidence of disease is not reported in the NIS, therefore surgical candidacy cannot be determined. Limitations also exist in data reporting. Certain data points of interest, in particular 19.6% of severity values, were missing from patient discharge records. This could lead to a skewed data set. ICD billing codes may also be inaccurate or incomplete.

Our findings demonstrate reduced advanced procedure utilization in women, Hispanic, and African American populations who are hospitalized with lumbar radiculopathy compared to men and white patients. The reasons remain unclear. Biases toward racial and ethnic minorities, as well as women, may play a significant role. Our results also show utilization discrepancies based on hospital geography and insurance coverage. More awareness from policymakers and providers is needed to address these barriers. We hope this serves as motivation for researchers to continue investigating solutions to health care disparities.

Conclusion

This study demonstrated that from 2016-2019, there were disparities in inpatient utilization of therapeutic procedures for lumbar radiculopathy. African American patients had the highest degree of illness severity. However, they were more likely to receive nonoperative management, ESI (OR = 1.52) and PT (OR = 1.65), over surgery and less likely to receive SCS (OR = 0.63). Hispanic patients were admitted with similar illness severity compared to white patients, but were more likely to receive nonoperative management, ESI (OR = 1.43) and PT (OR = 1.83), over surgery. Women were admitted with similar illness severity compared to men but were more likely to receive ESI over surgery (OR = 1.29). Patients admitted to urban hospital settings were less likely to receive surgery. Those insured by Medicaid were more likely to receive ESI (OR = 1.89) over surgery and less likely to receive SCS (OR = 0.52) compared to Medicare-insured patients. Future research in the outpatient setting can help explain these differences in more detail.

Author Contributions

RL designed the study, conducted research for the introduction and discussion, and wrote the first draft of the manuscript as well as revisions. DB ran statistical analyses and helped revise the manuscript. AR conceptualized the study and helped revise the manuscript. VS conceptualized the study, oversaw design, provided additional information, and helped revise the manuscript. All authors read and approved the final manuscript.

Acknowledgments

We would like to acknowledge the Emory Department of Anesthesia and all of the Healthcare Cost and Utilization Project (HCUP) Data partners that contribute to the HCUP. A list of the state organizations can be viewed here: https://hcup-us.ahrq.gov/db/hcupdatapartners.jsp.

Statement of Informed Consent

The National Inpatient Sample is an existing data set. It is a deidentified, limited sample that does not require an informed consent process. An institutional review board waiver was obtained prior to conducting the study. Detailed information can be found here: https://www.hcup-us.ahrq.gov/DUA/dua_508/DUA-508version.jsp

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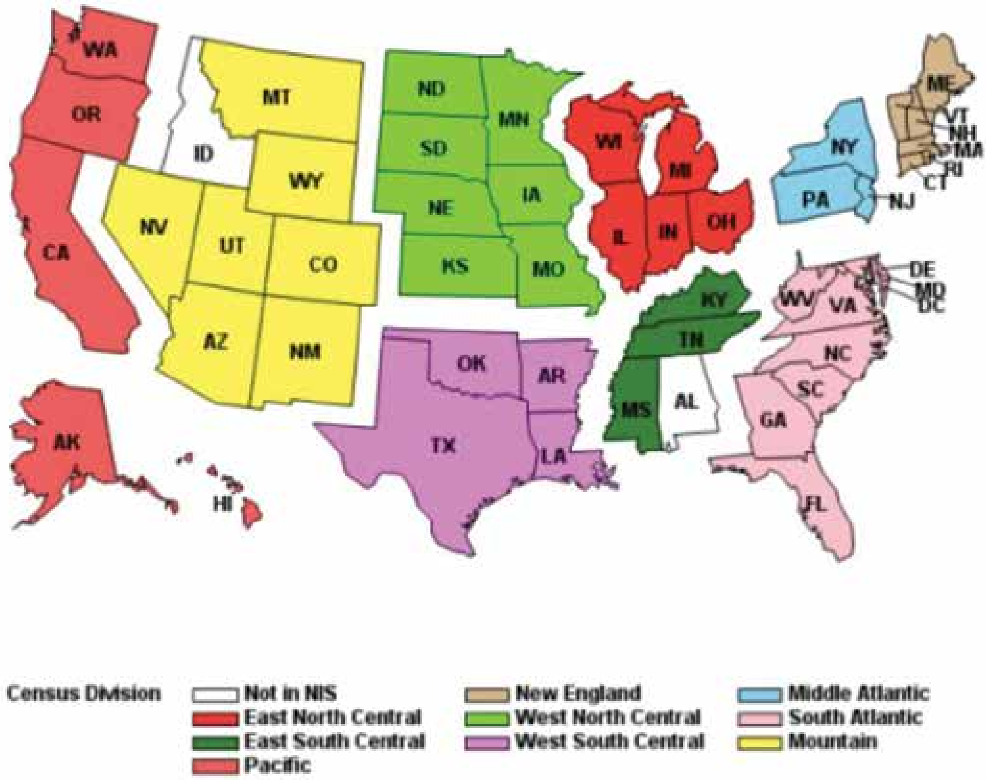

All States, by U.S Census Bureau Region and Census Division

- Region 1 (Northeast)
  - Division 1 (New England) Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut
  - Division 2 (Mid-Atlantic) New York, Pennsylvania, New Jersey
- Region 2 (Midwest[a])
  - Division 3 (East North Central) Wisconsin, Michigan, Illinois, Indiana, Ohio
  - Division 4 (West North Central) Missouri, North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa
- Region 3 (South)
  - Division 5 (South Atlantic) Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida
  - Division 6 (East South Central) Kentucky, Tennessee, Mississippi, *Alabama*
  - Division 7 (West South Central) Oklahoma, Texas, Arkansas, Louisiana
- Region 4 (West)
  - Division 8 (Mountain) *Idaho*, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico
  - Division 9 (Pacific) Alaska, Washington, Oregon, California, Hawaii

Supplemental Fig. 1. *NIS States by Census Division*.
From: https://www.hcup-us.ahrq.gov/db/nation/nis/NISIntroduction2019.pdf
Data from New Hampshire were unreported for the years 2016-2018. Idaho and Alabama do not participate in the NIS.

NIS Variable definitions

Population Density

Medium metropolitan counties have populations of 250,000-999,999. Small metropolitan counties have populations of 50,000-250,000. Non-metropolitan counties are considered rural and have populations of less than 49,999.

ZIP Code Median Income:

Income Quartile ($)	Year			
	2016	2017	2018	2019
Q1: 0-25	1-42,999	1-43,999	1-45,999	1-47,999
Q2: 26-50	43,000-53,999	44,000-55,999	46,000-58,999	48,000-60,999
Q3: 51-75	54,000-70,999	56,000-73,999	59,000-78,999	61,000-81,999
Q4: 76-100	71,000+	74,000+	79,000+	82,000+

ICD-10/PCS Codes

Physical Therapy:

RHB001 (Physical, occupational, and respiratory therapy evaluation): F0120EZ, F0120FZ, F0120UZ, F0120YZ, F0120ZZ, F0121ZZ, F0123ZZ, F0124ZZ, F0125YZ, F0125ZZ, F0126YZ, F0126ZZ, F012GZZ, F01G0EZ, F01G0FZ, F01G0UZ, F01G0YZ, F01G0ZZ, F01G1ZZ, F01G5YZ, F01G5ZZ, F01G6YZ, F01G6ZZ, F01L0EZ, F01L0FZ, F01L0UZ, F01L0YZ, F01L0ZZ, F01L1ZZ, F01L5YZ, F01L5ZZ, F01L6YZ, F01L6ZZ, F022DYZ, F022DZZ, F026GCZ, F026GGZ, F026GYZ, F026GZZ, F02BGCZ, F02BGGZ, F02BGYZ, F02BGZZ, F01ZDEZ, F01ZDFZ, F01ZDUZ, F01ZDYZ, F01ZDZZ

RHB002 (Physical, occupational, and respiratory therapy treatment): F0720EZ, F0720FZ, F0720UZ, F0720YZ, F0720ZZ, F0721EZ, F0721FZ, F0721UZ, F0721YZ, F0721ZZ, F0722EZ, F0722FZ, F0722UZ, F0722YZ, F0722ZZ, F0723EZ, F0723FZ, F0723UZ, F0723YZ, F0723ZZ, F0726BZ, F0726CZ, F0726DZ, F0726EZ, F0726FZ, F0726GZ, F0726HZ, F0726UZ, F0726YZ, F0726ZZ, F0727ZZ, F0766BZ, F0766CZ, F0766DZ, F0766EZ, F0766FZ, F0766GZ, F0766HZ, F0766UZ, F0766YZ, F0766ZZ, F07B6BZ, F07B6CZ, F07B6DZ, F07B6EZ, F07B6FZ, F07B6GZ, F07B6HZ, F07B6UZ, F07B6YZ, F07B6ZZ, F07G0EZ, F07G0FZ, F07G0UZ, F07G0YZ, F07G0ZZ, F07G1EZ, F07G1FZ, F07G1UZ, F07G1YZ, F07G1ZZ, F07G2EZ, F07G2FZ, F07G2UZ, F07G2YZ, F07G2ZZ, F07G3EZ, F07G3FZ, F07G3UZ, F07G3YZ, F07G3ZZ, F07G6BZ, F07G6CZ, F07G6DZ, F07G6EZ, F07G6FZ, F07G6GZ, F07G6HZ, F07G6UZ, F07G6YZ, F07G6ZZ, F07G7ZZ, F07L0EZ, F07L0FZ, F07L0UZ, F07L0YZ, F07L0ZZ, F07L1EZ, F07L1FZ, F07L1UZ, F07L1YZ, F07L1ZZ, F07L2EZ, F07L2FZ, F07L2UZ, F07L2YZ, F07L2ZZ, F07L3EZ, F07L3FZ, F07L3UZ, F07L3YZ, F07L3ZZ, F07L6BZ, F07L6CZ, F07L6DZ, F07L6EZ, F07L6FZ, F07L6GZ, F07L6HZ, F07L6UZ, F07L6YZ, F07L6ZZ, F07L7ZZ, F08G5BZ, F08G5CZ, F08G5DZ, F08G5EZ, F08G5FZ, F08G5UZ, F08G5YZ, F08G5ZZ, F08L5BZ, F08L5CZ, F08L5DZ, F08L5EZ, F08L5FZ, F08L5UZ, F08L5YZ, F08L5ZZ, F07Z9CZ, F07Z9DZ, F07Z9EZ, F07Z9FZ, F07Z9GZ, F07Z9UZ, F07Z9YZ, F07Z9ZZ, F0FZCEZ, F0FZCFZ, F0FZCUZ, F0FZCZZ

Epidural Steroid Injection:

ADM016 (Administration of anti-inflammatory agents): 3E0S33Z, 3E0R33Z

Spinal Cord Stimulator:

CNS012 (Central nervous system neurostimulator procedures): 00HU0MZ, 00HU3MZ, 00HU4MZ, 00HV0MZ, 00HV3MZ, 00HV4MZ, 00PU0MZ, 00PU3MZ, 00PU4MZ, 00PV0MZ, 00PV3MZ, 00PV4MZ, 00WU0MZ, 00WU3MZ, 00WU4MZ, 00WV0MZ, 00WV3MZ, 00WV4MZ

Surgery:

MST002 (Bone and joint biopsy): 0SB00ZX, 0SB03ZX, 0SB04ZX, 0SB20ZX, 0SB23ZX, 0SB24ZX, 0SB30ZX, 0SB33ZX, 0SB40ZX, 0SB43ZX, 0SB44ZX, 0QB03ZX

MST008 (Arthroplasty of other joint excluding knee and hip): 0SH008Z, 0SH038Z, 0SH048Z, 0SH208Z, 0SH238Z, 0SH248Z, 0SH308Z, 0SH338Z, 0SH348Z, 0SH408Z, 0SH438Z, 0SH448Z, 0SP008Z, 0SP00JZ, 0SP038Z, 0SP03JZ, 0SP048Z,

0SP04JZ, 0SP20JZ, 0SP23JZ, 0SP24JZ, 0SP308Z, 0SP30JZ, 0SP338Z, 0SP33JZ, 0SP348Z, 0SP34JZ, 0SP40JZ, 0SP43JZ, 0SP44JZ, 0SR007Z, 0SR00JZ, 0SR00KZ, 0SR207Z, 0SR20JZ, 0SR20KZ, 0SR307Z, 0SR30JZ, 0SR30KZ, 0SR407Z, 0SR40JZ, 0SR40KZ, 0SU007Z, 0SU00JZ, 0SU00KZ, 0SU037Z, 0SU03JZ, 0SU03KZ, 0SU047Z, 0SU04JZ, 0SU04KZ, 0SU207Z, 0SU20JZ, 0SU20KZ, 0SU237Z, 0SU23JZ, 0SU23KZ, 0SU247Z, 0SU24JZ, 0SU24KZ, 0SU307Z, 0SU30JZ, 0SU30KZ, 0SU337Z, 0SU-33JZ, 0SU33KZ, 0SU347Z, 0SU34JZ, 0SU34KZ, 0SU407Z, 0SU40JZ, 0SU40KZ, 0SU437Z, 0SU43JZ, 0SU43KZ, 0SU447Z, 0SU44JZ, 0SU44KZ, 0SW007Z, 0SW008Z, 0SW00JZ, 0SW00KZ, 0SW037Z, 0SW038Z, 0SW03JZ, 0SW03KZ, 0SW047Z, 0SW048Z, 0SW04JZ, 0SW04KZ, 0SW0X7Z, 0SW0X8Z, 0SW0XJZ, 0SW0XKZ, 0SW207Z, 0SW20JZ, 0SW20KZ, 0SW237Z, 0SW23JZ, 0SW23KZ, 0SW247Z, 0SW24JZ, 0SW24KZ, 0SW2X7Z, 0SW2XJZ, 0SW2XKZ, 0SW307Z, 0SW308Z, 0SW30JZ, 0SW30KZ, 0SW337Z, 0SW338Z, 0SW33JZ, 0SW33KZ, 0SW347Z, 0SW348Z, 0SW34JZ, 0SW34KZ, 0SW3X7Z, 0SW3X8Z, 0SW3XJZ, 0SW3XKZ, 0SW407Z, 0SW40JZ, 0SW40KZ, 0SW437Z, 0SW43JZ, 0SW43KZ, 0SW447Z, 0SW44JZ, 0SW44KZ, 0SW4X7Z, 0SW4XJZ, 0SW4XKZ

MST012 (Bone fixation excluding extremities): 0QH004Z, 0QH005Z, 0QH034Z, 0QH035Z, 0QH044Z, 0QH045Z, 0QP004Z, 0QP005Z, 0QP034Z, 0QP035Z, 0QP044Z, 0QP045Z, 0QP0X4Z, 0QP0X5Z, 0QS003Z, 0QS004Z, 0QS00ZZ, 0QS034Z, 0QS03ZZ, 0QS043Z, 0QS044Z, 0QS04ZZ, 0QW004Z, 0QW034Z, 0QW044Z, 0QW0X4Z, XNS0032, XNS00C7, XNS0332, XNS03C7, XNS0432

MST013 (Spine fusion): 0SG0070, 0SG0071, 0SG007J, 0SG00A0, 0SG00A1, 0SG00AJ, 0SG00J0, 0SG00J1, 0SG00JJ, 0SG00K0, 0SG00K1, 0SG00KJ, 0SG00Z0, 0SG00Z1, 0SG00ZJ, 0SG0370, 0SG0371, 0SG037J, 0SG03A0, 0SG03A1, 0SG03AJ, 0SG03J0, 0SG03J1, 0SG03JJ, 0SG03K0, 0SG03K1, 0SG03KJ, 0SG03Z0, 0SG03Z1, 0SG03ZJ, 0SG0470, 0SG0471, 0SG047J, 0SG04A0, 0SG04A1, 0SG04AJ, 0SG04J0, 0SG04J1, 0SG04JJ, 0SG04K0, 0SG04K1, 0SG04KJ, 0SG04Z0, 0SG04Z1, 0SG04ZJ, 0SG1070, 0SG1071, 0SG107J, 0SG10A0, 0SG10A1, 0SG10AJ, 0SG10J0, 0SG10J1, 0SG10JJ, 0SG10K0, 0SG10K1, 0SG10KJ, 0SG10Z0, 0SG10Z1, 0SG10ZJ, 0SG1370, 0SG1371, 0SG137J, 0SG13A0, 0SG13A1, 0SG13AJ, 0SG13J0, 0SG13J1, 0SG13JJ, 0SG13K0, 0SG13K1, 0SG13KJ, 0SG13Z0, 0SG13Z1, 0SG13ZJ, 0SG1470, 0SG1471, 0SG147J, 0SG14A0, 0SG14A1, 0SG14AJ, 0SG14J0, 0SG14J1, 0SG14JJ, 0SG14K0, 0SG14K1, 0SG14KJ, 0SG14Z0, 0SG14Z1, 0SG14ZJ, 0SG3070, 0SG3071, 0SG307J, 0SG30A0, 0SG30A1, 0SG30AJ, 0SG30J0, 0SG30J1, 0SG30JJ, 0SG30K0, 0SG30K1, 0SG30KJ, 0SG30Z0, 0SG30Z1, 0SG30ZJ, 0SG3370, 0SG3371, 0SG337J, 0SG33A0, 0SG33A1, 0SG33AJ, 0SG33J0, 0SG33J1, 0SG33JJ, 0SG33K0, 0SG33K1, 0SG33KJ, 0SG33Z0, 0SG33Z1, 0SG33ZJ, 0SG3470, 0SG3471, 0SG347J, 0SG34A0, 0SG34A1, 0SG34AJ, 0SG34J0, 0SG34J1, 0SG34JJ, 0SG34K0, 0SG34K1, 0SG34KJ, 0SG34Z0, 0SG34Z1, 0SG34ZJ, 0SH004Z, 0SH00BZ, 0SH00CZ, 0SH00DZ, 0SH034Z, 0SH03BZ, 0SH03CZ, 0SH03DZ, 0SH044Z, 0SH04BZ, 0SH04CZ, 0SH04DZ, 0SH304Z, 0SH-30BZ, 0SH30CZ, 0SH30DZ, 0SH334Z, 0SH33BZ, 0SH33CZ, 0SH33DZ, 0SH344Z, 0SH34BZ, 0SH34CZ, 0SH34DZ, 0SP004Z, 0SP00AZ, 0SP034Z, 0SP03AZ, 0SP044Z, 0SP04AZ, 0SP0X4Z, 0SP304Z, 0SP30AZ, 0SP334Z, 0SP33AZ, 0SP344Z, 0SP34AZ, 0SP3X4Z, 0SS004Z, 0SS00ZZ, 0SS034Z, 0SS03ZZ, 0SS044Z, 0SS04ZZ, 0SS0X4Z, 0SS304Z, 0SS30ZZ, 0SS334Z, 0SS33ZZ, 0SS344Z, 0SS34ZZ, 0SS3X4Z, 0SW004Z, 0SW00AZ, 0SW034Z, 0SW03AZ, 0SW044Z, 0SW04AZ, 0SW0X4Z, 0SW0XAZ, 0SW304Z, 0SW30AZ, 0SW334Z, 0SW33AZ, 0SW344Z, 0SW34AZ, 0SW3X4Z, 0SW3XAZ, XRGB092, XRGB0F3, XRGB0R7, XRGB3R7, XRGB4R7, XRGC092, XRGC0F3, XRGC0R7, XRGC3R7, XRGC4R7, XRGD092, XRGD0F3, XRGD0R7, XRGD3R7, XRGD4R7

MST016 (Vertebral discectomy): 0S520ZZ, 0S523ZZ, 0S524ZZ, 0S540ZZ, 0S543ZZ, 0S544ZZ, 0SB20ZZ, 0SB23ZZ, 0SB24ZZ, 0SB40ZZ, 0SB43ZZ, 0SB44ZZ, 0ST20ZZ, 0ST40ZZ

MST017 (Joint tissue excision excluding discectomy): 0ST40ZZ, 0S500ZZ, 0S503ZZ, 0S504ZZ, 0S530ZZ, 0S533ZZ, 0S534ZZ, 0SB00ZZ, 0SB03ZZ, 0SB04ZZ, 0SB30ZZ, 0SB33ZZ, 0SB34ZZ

MST018 (Bone excision): 0Q500ZZ, 0Q503ZZ, 0Q504ZZ, 0QB00ZZ, 0QB03ZZ, 0QB04ZZ, 0QD00ZZ

MST030 (Musculoskeletal procedures): 0SC00ZZ, 0SC03ZZ, 0SC20ZZ, 0SC23ZZ, 0SC24ZZ, 0SC30ZZ, 0SC33ZZ, 0SC-34ZZ, 0SC40ZZ, 0SC43ZZ, 0SN00ZZ, 0SN03ZZ, 0SN04ZZ, 0SN0XZZ, 0SN20ZZ, 0SN23ZZ, 0SN2XZZ, 0SN30ZZ, 0SN33ZZ, 0SN34ZZ, 0SN40ZZ, 0SQ00ZZ, 0SQ03ZZ, 0SQ20ZZ, 0SQ23ZZ, 0SQ30ZZ, 0SQ33ZZ, 0SQ40ZZ, 0SQ44ZZ

PNS001 (Lumbosacral nerve decompression): 01NB0ZZ, 01NB3ZZ, 01NB4ZZ, 01NR0ZZ

PNS004 (Nerve repair): 01QB0ZZ, 01QB3ZZ, 01QB4ZZ, 01UB07Z, 01UB0JZ, 01UB0KZ, 01UB37Z, 01UB3JZ, 01UB-3KZ, 01UB47Z, 01UB4JZ, 01UB4KZ

PNS005 (Peripheral nerve denervation): 015B0ZZ, 015B3ZZ, 015B4ZZ, 01BB3ZZ, 01BB4ZZ, 01DB0ZZ, 01DB3ZZ, 01DB4ZZ, 018B0ZZ, 018B3ZZ, 018B4ZZ, 01BB0ZZ

PNS006 (Peripheral nerve procedures): 01BB0ZX, 01BB3ZX, 01BB4ZX, 01CB0ZZ, 01CB3ZZ, 01CB4ZZ, 01RB07Z, 01RB0JZ, 01RB0KZ, 01RB47Z, 01RB4JZ, 01RB4KZ, 01SB0ZZ, 01SB3ZZ, 01SB4ZZ

Supplemental Table 1. *Procedure category overlap.*

Outcome	Weighted Total (N)	Percent (%)
PT	2,355	
PT and ESI	30	1.3
PT and SCS	0	0
PT and Surgery	425	18.0
ESI	8,125	
ESI and PT	30	0.4
ESI and SCS	20	0.2
ESI and Surgery	885	10.9
SCS	2,675	
SCS and PT	0	0
SCS and ESI	20	0.7
SCS and Surgery	630	23.5
Surgery	241,615	
Surgery and PT	425	0.2
Surgery and ESI	885	0.4
Surgery and SCS	630	0.3

Abbreviations: PT: Physical Therapy, ESI: Epidural Steroid Injections, SCS: Spinal Cord Stimulator

Of the patients who had PT, 18.0% also received surgery and very few to none received ESI or SCS. Of the patients who had ESI 10.9%, also received surgery and very few received PT or SCS. Of the patients who had SCS, 23.5% also received surgery and very few to none received PT or ESI. Of the patients who received surgery, minimal overlap was seen with other procedures. An overlap significant enough to effect odds ratios was only observed with PT and surgery, ESI and surgery, and SCS and Surgery. ESI and SCS are selected before surgery in the hierarchy, thus, their outcomes are not affected by the overlap. However, surgery is selected for before PT. From a clinical standpoint, PT is routinely done as part of the recovery from surgery whether as an inpatient or outpatient. When the 2 are performed together surgery is the primary treatment choice and PT is the adjunct. Therefore, PT should only be viewed as the primary treatment when done alone and the overlap with surgery is not clinically significant.

Supplemental Table 2. *Logistic regression – comparison of unadjusted to adjusted independent variables.*

Category	Variable/Reference	Value	Odds Ratio compared to Surgery (95% CI)[a]		
			ESI	PT	SCS
Demographics	Race-Ethnicity/White	African American	1.70 (1.44-1.99) 1.49 (1.25-1.78) 1.52 (1.25-1.84) 1.52 (1.26-1.84)	1.78 (1.27-2.49) 1.78 (1.25-2.52) 1.65 (1.11-2.46) 1.60 (1.11-2.30)	0.82 (0.58-1.17) 0.65 (0.45-0.92) 0.63 (0.42-0.94) 0.64 (0.43-0.95)
		Hispanic	1.44 (1.14-1.83) 1.44 (1.15-1.80) 1.43 (1.12-1.83) 1.42 (1.11-1.82)	1.94 (1.37-2.75) 2.05 (1.41-2.96) 1.83 (1.20-2.79) 1.70 (1.18-2.46)	1.01 (0.72-1.44) 0.87 (0.61-1.25) 0.88 (0.60-1.29) 0.86 (0.59-1.26)
		Other/ Unknown	1.06 (0.86-1.31) 1.02 (0.84-1.25) 0.99 (0.79-1.24) 0.99 (0.79-1.24)	1.32 (0.87-2.00) 1.35 (0.89-2.07) 1.41 (0.89-2.23) 1.55 (1.06-2.27)	0.83 (0.57-1.21) 0.85 (0.59-1.25) 0.91 (0.61-1.36) 0.91 (0.61-1.35)
	Age	Per decade	1.24 (1.17-1.32) 1.24 (1.16-1.33) 1.27 (1.17-1.37) 1.26 (1.17-1.36)	1.61 (1.44-1.81) 1.45 (1.27-1.68) 1.49 (1.28-1.76) 1.34 (1.17-1.55)	0.97 (0.91-1.04) 0.83 (0.75-0.90) 0.83 (0.74-0.91) 0.81 (0.73-0.90)
	Gender/Men	Women	1.31 (1.19-1.46) 1.24 (1.12-1.37) 1.29 (1.15-1.44) 1.28 (1.15-1.43)	1.30 (1.06-1.59) 1.19 (0.97-1.46) 1.19 (0.94-1.51) 1.18 (0.95-1.47)	1.16 (0.97-1.37) 1.12 (0.94-1.33) 1.11 (0.92-1.34) 1.10 (0.91-1.33)
Geography	Population Density/Urban	Med.-Rural	0.42 (0.36-0.48) 0.44 (0.37-0.51) 0.42 (0.35-0.51) 0.43 (0.36-0.52)	0.40 (0.29-0.57) 0.44 (0.29-0.65) 0.42 (0.27-0.66) 0.43 (0.29-0.64)	0.69 (0.56-0.87) 0.57 (0.46-0.73) 0.57 (0.44-0.74) 0.60 (0.47-0.78)
		Suburban	0.84 (0.72-0.97) 0.83 (0.71-0.97) 0.84 (0.71-1.00) 0.85 (0.72-1.01)	0.59 (0.44-0.88) 0.60 (0.39-0.92) 0.57 (0.35-0.95) 0.58 (0.37-0.90)	0.96 (0.76-1.22) 0.89 (0.69-1.14) 0.87 (0.66-1.14) 0.89 (0.68-1.17)
	Hospital Region/Northeast	Midwest	0.99 (0.81-1.21) 1.13 (0.92-1.39) 1.12 (0.91-1.38) 1.13 (0.91-1.39)	0.82 (0.44-1.52) 0.88 (0.47-1.65) 0.82 (0.42-1.60) 0.82 (0.44-1.54)	0.65 (0.49-0.88) 0.64 (0.47-0.86) 0.64 (0.47-0.86) 0.63 (0.47-0.86)
		South	0.53 (0.43-0.65) 0.60 (0.49-0.75) 0.64 (0.51-0.80) 0.64 (0.51-0.80)	0.98 (0.69-1.40) 1.04 (0.73-1.50) 0.88 (0.60-1.31) 1.06 (0.73-1.53)	0.75 (0.58-0.97) 0.73 (0.56-0.94) 0.74 (0.56-0.97) 0.76 (0.58-1.00)
		West	0.57 (0.46-0.72) 0.56 (0.44-0.71) 0.61 (0.48-0.79) 0.62 (0.48-0.80)	0.85 (0.55-1.32) 0.72 (0.45-1.15) 0.63 (0.39-1.01) 0.84 (0.52-1.37)	0.53 (0.39-0.72) 0.52 (0.38-0.71) 0.53 (0.38-0.74) 0.55 (0.39-0.77)
	ZIP Code Median Income Quartile/Q4: 76-100	Q1: 0-25	0.80 (0.68-0.95) 1.02 (0.85-1.22) 1.03 (0.85-1.26) 1.03 (0.84-1.26)	0.77 (0.54-1.10) 1.45 (1.27-1.68) 0.96 (0.64-1.44) 1.02 (0.70-1.48)	1.31 (1.01-1.69) 0.83 (0.75-0.90) 0.83 (0.74-0.91) 1.54 (1.12-2.12)
		Q2: 26-50	0.68 (0.58-0.79) 0.88 (0.75-1.03) 0.87 (0.73-1.03) 0.87 (0.73-1.03)	0.82 (0.66-1.13) 1.19 (0.97-1.46) 0.92 (0.64-1.31) 0.93 (0.66-1.31)	1.13 (0.87-1.46) 1.12 (0.94-1.33) 1.11 (0.92-1.34) 1.36 (1.00-1.84)
		Q3: 51-75	0.76 (0.66-0.88) 0.87 (0.76-1.01) 0.87 (0.75-1.02) 0.87 (0.75-1.02)	0.79 (0.58-1.08) 0.81 (0.55-1.21) 0.94 (0.68-1.30) 1.00 (0.73-1.37)	1.31 (1.02-1.68) 1.63 (1.23-2.17) 1.55 (1.13-2.13) 1.54 (1.18-2.01)

Supplemental Table 2 cont. *Logistic regression – comparison of unadjusted to adjusted independent variables*.

Category	Variable/Reference	Value	Odds Ratio compared to Surgery (95% CI)[a]		
			ESI	PT	SCS
Pay	Primary Payer /Medicare	Medicaid	1.42 (1.20-1.68) 1.89 (1.56-2.29) 1.89 (1.53-2.33) 1.89 (1.53-2.33)	0.61 (0.40-0.92) 1.06 (0.65-1.73) 1.04 (0.60-1.78) 1.01 (0.62-1.66)	0.72 (0.50-1.03) 0.47 (0.30-0.73) 0.52 (0.33-0.83) 0.52 (0.33-0.82)
		Private /Other	0.51 (0.46-0.58) 0.69 (0.60-0.79) 0.67 (0.57-0.79) 0.68 (0.58-0.79)	0.30 (0.23-0.40) 0.50 (0.37-0.66) 0.54 (0.39-0.75) 0.63 (0.47-0.84)	0.66 (0.55-0.80) 0.49 (0.38-0.64) 0.48 (0.36-0.64) 0.49 (0.37-0.64)
APD-DRG	Severity /Minor	Major/Ext	1.01 (0.85-1.21) Omitted 0.81 (0.68-0.97) 0.79 (0.66-0.94)	4.52 (3.16-6.49) Omitted 3.36 (2.30-4.91) 3.14 (2.25-4.39)	1.41 (1.05-1.90) Omitted 1.37 (1.01-1.85) 1.41 (1.05-1.89)
		Moderate	0.55 (0.48-0.62) Omitted 0.48 (0.42-0.55) 0.48 (0.42-0.55)	1.34 (0.98-1.84) Omitted 1.13 (0.82-1.56) 1.21 (0.92-1.60)	1.01 (0.82-1.25) Omitted 0.98 (0.79-1.21) 1.01 (0.82-1.25)

Model Legend:
- Top row: Odds ratio unadjusted for other confounders. Full dataset. No data imputed. Hierarchical outcome (ESI>SCS>Surgery>PT)
- Second row: Adjusted for all confounders except Severity. Full dataset. Hierarchical outcome. Limited imputation of some variables.
- Third row: Adjusted for all confounders including Severity; 19.6% of data missing. Hierarchical outcome. This is the main model displayed in Figure 3 of the main manuscript.
- Bottom row: Isolated outcomes (ESI Yes/No, etc.), so overlap from multiple procedures is irrelevant. Most important for PT, which saw a 18.0% overlap with surgery; see Table S1. Adjusted for all confounders including severity; 19.6% of data missing.
- Underline: Confidence interval crosses 1.0; odds ratio is not statistically significant.
- Double-lined boxes: Adjusted models show larger variation, indicating results are less reliable.

a Top/2nd row/3rd row/Bottom: unadjusted/adjusted models, without/with severity. Missing 10,962 in severity. Bottom: outcomes isolated (ESI Yes/No). Underlined confidence intervals are not statistically significant. Double-lined boxes have larger variations between adjusted models. Abbreviations: Med-Rural: medium to rural counties; 95% CI: 95% confidence interval; NS: not statistically significant; PT: Physical Therapy; ESI: Epidural Steroid Injections; SCS: Spinal Cord Stimulator

Table S2 shows the adjusted logistic regression without the APR-DRG Severity variable and the unadjusted logistic regression. Because data were missing for 10,778 observations (19.6% of the data), it was felt that imputing data for that variable would be inappropriate. Therefore, the logistic regression was performed with the full data but without the severity variable (black, 2nd row) and with the severity variable (red, 3rd row, and Fig. 3 of the main document). For white patients 19.6% of severity data was missing, for African American patients 20.9%, and for Hispanic patients 21.1%. The purple odds ratios show models where the outcomes are isolated from each other (ESI Yes/No, PT Yes/No, SCS Yes/No), to account for overlap from patients who had multiple procedures. This is most relevant for PT, where the overlap with surgery was high (18.0%).

Comparison of the adjusted models show odds ratios are similar regardless of the model. Exceptions where the odds ratio are more divergent (marked by double outlined boxes) occur primarily within the ZIP Code median income quartile variable, which was the weakest predictor. Some divergence also occurs within geographic region, although these occur within statistically insignificant comparisons. Race was very stable for ESI and SCS and reasonably stable for PT. Thus, use of the red logistic regression model is justified.

Sample SAS Code

Portions of the SAS code used to filter the data and perform the logistic regression.

```
* Impute missing data;
* Missing Female N=4, Pay1 N=77, PL_NCHS N=87, ZipInc_qrtl N=837, elective N=148, AWeekend N=1, I10_Injury N=40584, I10_Serviceline N=40584 ;
* Impute data Bayesian bootstrap hot-deck imputation method; * https://documentation.sas.com/doc/en/statcdc/14.2/statug/statug_surveyimpute_examples01.htm ;
* Full analysis details:  https://support.sas.com/rnd/app/stat/procedures/SurveyAnalysis.html  ;

proc surveyimpute     data=br method=hotdeck(selection=abb)
ndonors=5;
    var               Female Pay1 PL_NCHS Elective AWeekend LOS
ZipInc_Qrtl;
    weight  Discwt;
    cluster Hosp_NIS;
    strata  NIS_Stratum;
    output  out=brabb;
run;

* Set Weight 1/5 for imputed values to reduce weighted number of imputed donors from 5 back down to 1;
data brabb;
    set brabb;
    if ImpIndex > 0 then discwt = discwt/5;
run;
*************************************************************;
* Weighted frequency of categorical variables;
proc surveyfreq data=br;
    format  Race Race.
            PL_NCHS PL_NCHS.
            Elective Elective.
            ZipInc_Qrtl ZipInc_Qrtl.;
    weight  Discwt;
    cluster Hosp_NIS;
    strata  NIS_Stratum;
    tables  Race Year Female MDC Hosp_Division I10_Injury
            I10_Serviceline I10_NDx I10_NPR Pay1 PL_NCHS
            ZipInc_Qrtl Elective AWeekend
            APRDRG_Risk_Mortality APRDRG_Severity;
run;

* Weighted means of continuous variables;
proc surveymeans data=br;
    var     age LOS TotChg I10_NDx I10_NPR;
    weight  Discwt;
    cluster Hosp_NIS;
    strata  NIS_Stratum;
run;

* Weighted Logistic Regression, single predictor;
```

```
* Model 3.3  Out2 vs Race 4 gp;
proc surveylogistic data=br;
      weight   Discwt;
      cluster  Hosp_NIS;
      strata   NIS_Stratum;
      format   Race Race4gp. ;
      /* Black, White, Hispanic, Other/Unknown */
      class    Race (ref=last);
      model    Out2 (ref=last) = Race / link=glogit;
               * glogit for multinomial logistic regression;
run;
```