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Provider's exposure to diversity contributes to socioeconomic disparities in lumbar and cervical fusion outcomes

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ABSTRACT

Background: Studies report patient race, income, and education influence spinal fusion outcomes; fewer studies, however, examine the influence of provider factors such as exposure to diversity or cultural sensitivity.
Objective: To examine how providers' experience with diverse patient populations affects spinal fusion outcomes.
Methods: Retrospective review of 39,680 patients undergoing lumbar and cervical fusions, 2003–2021, in Clinformatics® Data Mart national database. We used the provider patient racial diversity index (pRDI)—a published metric of physician exposure to diverse patients—to divide patients into groups based their provider's category (I, II, III) where patients treated by category III providers had surgeons with the most diverse patient populations. Multivariate regression models on propensity score-matched cohorts examined the association between patient SES and provider category on post-operative outcomes.
Results: Black patients had decreased discharge home (OR 0.67; 95% CI 0.54–0.83) compared to white patients. Patients treated by category III providers had increased length of stay (Coeff. 0.62; 95% CI 0.43–0.81), charge (Coeff. 36800; 95% CI 29,200–44,400), and decreased discharge home (OR 0.90; 95% CI 0.83–0.97) compared to patients treated by category I providers. Asian patients treated by category II providers had decreased readmission (OR 0.38; 95% CI 0.14–0.96), and Black patients treated by category III providers had increased discharge home (OR 1.41; 95% CI 1.1–1.9) compared to those treated by category I providers.
Conclusion: While our study found two specific instances of improved spine surgery outcomes for minority patients treated by providers serving diverse patient populations, we present mixed findings overall. This study serves as the foundation for future research to better understand how provider pRDI affects outcomes in patients undergoing lumbar and cervical spine surgery.

1. Introduction

Cervical and lumbar spinal fusion procedures in the United States (U.S.) continue to rise with a 2.1-fold (114%) and 2.7-fold (171%) increase from 1998 to 2008, respectively.[1] However, socioeconomic status (SES) continues to influence disparities in post-operative outcomes.[2]

Previous studies examining the influence of SES on spine surgery outcomes have focused on patient-level factors including race/ethnicity, income, education, and insurance type.[3] However, limited studies have examined the influence of provider-level factors (e.g., exposure to diversity, cultural sensitivity) on post-surgical outcomes. A recent study introduced a novel metric–the provider patient racial diversity index (pRDI)–defined as the proportion of non-white patients comprising a physician's total patient population.[4] The provider pRDI quantifies the diversity of a surgeon's patient pool and may indicate cultural competence and sensitivity, which has been associated in some studies with

Abbreviations: U.S., United States; CDM, Clinformatics® Data Mart; SES, socioeconomic status; provider pRDI, provider patient racial diversity index; LOS, length of stay; ER, emergency room; CPT, Current Procedural Terminology; ICD, International Classification of Diseases; CCI, Charlson Comorbidity Index; HMO, Health Maintenance Organization; IND, indemnity; EPO, Exclusive Provider Organization; POS, point-of-service; PPO, Preferred Provider Organization; OTH, other; SMD, Standardized Mean Difference; OR, odds ratio; Coeff, coefficient; CI, confidence interval; SF-36, Short Form-36; EQ-5D, EuroQol-5D; ODI, Oswestry Disability Index; MIS, Minimally Invasive Surgery.

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improved outcomes in minority patients.[5,6] In support of past findings, Jin et al. found increased provider pRDI (i.e.,physicians serving diverse patient populations) was associated with increased palliative care referral and utilization of supportive care services for patients with central nervous system malignancy. Similar studies in the spinal fusion patient population are needed to understand how a surgeon's exposure to a diverse patient population may impact post-operative outcomes.

To that end, our study aimed to retrospectively analyze cervical and lumbar spinal fusion outcomes of patients in a large national insurance claims database to assess the influence of provider pRDI on post-operative outcomes. We hypothesized surgeons who care for diverse patient populations will have improved outcomes for minority patients. Outcomes include hospital length of stay (LOS), total hospital charges, out-of-pocket charges, and rates of 30-day readmission, post-operative complications, emergency room (ER) visits, and discharge to home (versus inpatient rehab, skilled nursing facilities, or other locations). To our knowledge, this is the first study examining the effect of provider exposure to diversity and its interaction with patient socioeconomic factors on spinal fusion outcomes.

2. Material and methods

2.1. Study population

We queried Clinformatics® Data Mart (CDM) for adult patients (≥ 18 years) undergoing first time, inpatient lumbar and cervical spinal fusion from January 1, 2003 to March 31, 2021 using Current Procedural Terminology (CPT) inclusion codes (Supplementary Table 1). 39,680 patients were identified. CDM contains de-identified insurance claims for outpatient, inpatient, and pharmaceutical services. CDM comprises >75 million U.S. employees, retirees, and dependents and provides granular socioeconomic data representing a significant portion of the commercially insured U.S. population. We excluded patients with missing socioeconomic data.

2.2. Provider patient racial diversity index

We calculated the provider pRDI as the proportion of non-white minority patients with a billed insurance claim to each patients' neurosurgeon or orthopedic surgeon.[4] We then divided our patients into tertiles (I, II, and III) based on the provider pRDI. In this manner, patients in category III were treated by surgeons with the most racially diverse patient populations compared to categories I and II. To further characterize the provider pRDI, we geographically mapped the number of lumbar and cervical fusions by U.S. state and the mean provider pRDI.

2.3. Outcome measures

Our primary outcomes were hospital length of stay, and rates of readmission, reoperation, and post-operative complication within 30-days from the date of surgery. Post-operative complications include myocardial infarction, pulmonary embolism, pneumonia, stroke, acute kidney injury, sepsis, urinary tract infection, deep vein thrombosis, wound infection, cerebrospinal fluid leak, implant failure, and others as defined by ICD-9/10 diagnosis codes (Supplementary Table 2). Our secondary outcomes include rates of 30-day post-operative ER visits, discharge status (home versus other), total hospital charges, and out-of-pocket charges (in U.S dollars). Patient demographic variables include age, sex, year of surgery, Charlson Comorbidity Index (CCI), and insurance type (Health Maintenance Organization (HMO), indemnity (IND), Exclusive Provider Organization (EPO), point-of-service (POS), Preferred Provider Organization (PPO), other (OTH)). Socioeconomic variables include race (Black, Hispanic, Asian, White), net worth (<$25K, $25K-$149K, $150-$249K, $250-$499K, >$500K) and education (high school diploma or less, Bachelor's degree or less, greater than Bachelor's degree). Hospital characteristics include bed size (small, <100; medium, 101–249; large, >250). Variable categories were predefined by CDM.

2.4. Statistical analysis

Continuous variables were summarized using mean with standard deviation and compared with *t*-tests; categorical variables were summarized with frequency and proportion and compared with chi-squared tests. Statistically significant results were considered *p*-values of ≤0.05 or significant effect sizes were considered standardized mean differences (SMD) of ≥0.2. We used propensity score matching with a 1:1:1 greedy algorithm to create a matched cohort with balanced demographic (age, sex, CCI, year of surgery, insurance type) and socioeconomic characteristics (race, net worth, education). The propensity scores were generated using multinomial logistic regression with the provider category as the outcome variable. We then used multivariate linear and logistic regression models on our propensity matched cohort to analyze the effect of provider pRDI (i.e., category I, II, and III) on outcome measures. We included interaction terms for provider pRDI and patient race to examine the association between the diversity of a surgeon's patient population and the patient's race with post-operative outcomes. Statistical analysis was completed using GraphPad Prism 8 (GraphPad Software, San Diego, CA, USA) and R statistical programming language version 4.1 (Vienna, Austria). Our study was approved by the Institutional Review Board (IRB #40974) under which patient consent was not required due to the use of de-identified insurance claims data. Our study complies with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

3. Results

A total of 39,680 patients underwent lumbar and cervical fusions, 2003–2021, in CDM. The mean provider pRDI for all patients was 0.23 (SD 0.15) (Fig. 1A). Patients were divided into categories I ($n = 13,380$), II ($n = 13,152$), and III (n = 13,148) using provider pRDI of 0–0.15, 0.15–0.26, and 0.26–1, respectively. Texas and Florida had the most lumbar and cervical fusions compared to all other states (Fig. 1B) with 5,772 and 5,113, respectively, and totaling 25% of all U.S. surgeries. Hawaii, South Carolina, and Georgia had the highest mean provider pRDI (Fig. 1C), with 0.53, 0.40, and 0.39, respectively.

Unmatched cohort characteristics are depicted in Table 1. Prior to cohort matching, the greatest percentage of minority patients were in category III, followed by category II, and I (38.5%, 17.4%, and 8.7% respectively). This is expected, based on our definition of the pRDI categories. A higher proportion of patients in category III compared with category I had a high school diploma or less (36% vs 25%; SMD = 0.25) and a lower proportion of patients had a bachelor's degree (50% vs 62%). Patients in category I and II differed in insurance type (SMD = 0.26). Lastly, a higher proportion of category III compared to category I patients were treated in small-bed hospitals (48% vs 42%; SMD = 0.34) and a lower proportion in large-bed hospitals (7% vs 17%).

Cohort was successfully matched for year of surgery, age, sex, CCI, race, net worth, education level and insurance type (Table 2). Bed size was not included in the matching algorithm due to the high number of unknowns with 23%, 25%, and 31% for category I, II, and III, respectively.

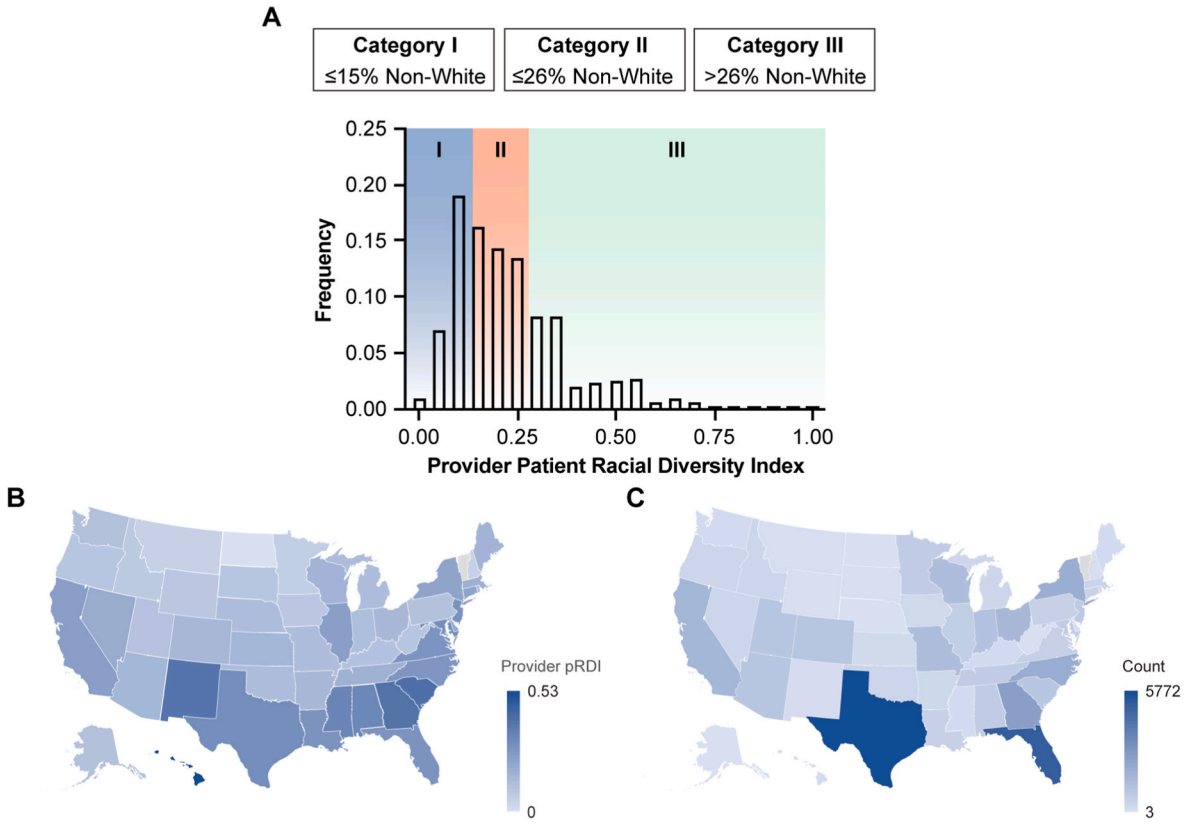

Fig. 1. (A) Histogram of the provider patient racial diversity index divided into three categories with defined cut-offs. U.S. map of (B) the provider patient racial diversity index and (C) the number of lumbar and cervical fusion surgeries by state. Total $n = 39{,}680$.

Table 1
Unmatched cohort characteristics. Total $n = 39,680$.

	Category I (ref)	Category II	Category III	SMD (I vs II)	SMD (I vs III)
	(n = 13,380)	(n = 13,152)	(n = 13,148)		
Characteristic					
Year of surgery, mean (SD)	2015.14 (3.06)	2015.62 (2.97)	2015.63 (2.98)	0.161	0.164
Age, years, mean (SD)	61.33 (13.01)	59.05 (13.10)	60.47 (13.14)	0.175	0.066
Sex, n (%)				**0.022**	**0.026**
Female (ref)	7,095 (53.0)	7,117 (54.1)	7,141 (54.4)		
Male	6,285 (47.0)	6,035 (45.9)	6,007 (45.7)		
CCI, mean (SD)	2.49 (2.49)	2.58 (2.55)	2.91 (2.80)	0.033	0.159
Race, n (%)				**0.264**	**0.755**
White (ref)	12,220 (91.3)	10,867 (82.6)	8,089 (61.5)		
Asian	160 (1.2)	232 (1.8)	380 (2.9)		
Black	544 (4.1)	1,193 (9.1)	2,844 (21.6)		
Hispanic	456 (3.4)	860 (6.5)	1,835 (14.0)		
Net Worth, n (%)				0.082	0.188
>500k (ref)	3,625 (27.1)	3,870 (29.4)	3,232 (24.6)		
<$25k	2,995 (22.4)	3,118 (23.7)	3,914 (29.8)		
$25K-$149k	2,664 (19.9)	2,570 (19.5)	2,659 (20.2)		
$150K-$249k	1,565 (11.7)	1,327 (10.1)	1,414 (10.8)		
$250K-$499k	2,531 (18.9)	2,267 (17.2)	1,929 (14.7)		
Education Level, n (%)				0.154	**0.248**
Greater than Bachelor's Degree (ref)	1,759 (13.1)	2,457 (18.7)	1,873 (14.2)		
High school diploma or less	3,375 (25.2)	3,251 (24.7)	4,691 (35.7)		
Less than Bachelor's Degree	8,246 (61.6)	7,444 (56.6)	6,584 (50.1)		
Insurance, n (%)				**0.259**	0.195
EPO	572 (4.3)	965 (7.3)	1,114 (8.5)		
HMO	1,468 (11.0)	1,172 (8.9)	1,612 (12.3)		
IND	176 (1.3)	110 (0.8)	85 (0.6)		
OTH	4,822 (36.0)	3,519 (26.8)	4,643 (35.3)		
POS	5,176 (38.7)	6,163 (46.9)	4,653 (35.4)		
PPO	1,166 (8.7)	1,223 (9.3)	1,041 (7.9)		
Hospital bed size, n (%)				0.111	**0.343**
Small (<100)	5,555 (41.5)	4,897 (37.2)	6,311 (48.0)		
Medium (101–249)	2,503 (18.7)	2,360 (17.9)	1,928 (14.7)		
Large (>250)	2,214 (16.5)	2,619 (19.9)	927 (7.1)		
Unknown	3,108 (23.2)	3,276 (24.9)	3,982 (30.3)		

Bold text indicates significant effect size (SMD ≥0.2).

Multivariate regression models were used to determine the relative effect of SES variables, provider pRDI category, and the interaction between race and category on surgical outcomes independent of age, sex, year of surgery, comorbidities, and insurance type (Tables 3 and 4).

Table 2
Matched cohort characteristics. Matched variables: year of surgery, age, sex, CCI, race, net worth, education, and insurance type. Total $n = 17,291$.

	Category I (ref)	Category II	Category III	SMD (I vs II)	SMD (I vs III)
	(n = 8,234)	(n = 8,234)	(n = 8,234)		
Characteristic					
Year of surgery, mean (SD)	2015.44 (3.06)	2015.49 (3.00)	2015.46 (2.97)	0.018	0.01
Age, years, mean (SD)	60.49 (13.08)	60.51 (12.99)	60.36 (13.14)	0.002	0.010
Sex, n (%)				0.012	0.011
Female (ref)	4,326 (52.5)	4,377 (53.2)	4,372 (53.1)		
Male	3,908 (47.5)	3,857 (46.8)	3,862 (46.9)		
CCI, mean (SD)	2.65 (2.65)	2.70 (2.61)	2.65 (2.61)	0.017	0.001
Race, n (%)				0.013	0.026
White (ref)	7,192 (87.3)	7,182 (87.2)	7,141 (86.7)		
Asian	139 (1.7)	140 (1.7)	157 (1.9)		
Black	486 (5.9)	508 (6.2)	525 (6.4)		
Hispanic	417 (5.1)	404 (4.9)	411 (5.0)		
Net Worth, n (%)				0.022	0.009
>500k (ref)	2,409 (29.3)	2,390 (29.0)	2,392 (29.1)		
<$25k	1,895 (23.0)	1,967 (23.9)	1,907 (23.2)		
$25K-$149k	1,602 (19.5)	1,601 (19.4)	1,591 (19.3)		
$150K-$249k	927 (11.3)	909 (11.0)	920 (11.2)		
$250K-$499k	1,401 (17.0)	1,367 (16.6)	1,424 (17.3)		
Education Level, n (%)				0.034	0.012
Greater than Bachelor's Degree (ref)	1,422 (17.3)	1,320 (16.0)	1,391 (16.9)		
High school diploma or less	2,295 (27.9)	2,355 (28.6)	2,280 (27.7)		
Less than Bachelor's Degree	4,517 (54.9)	4,559 (55.4)	4,563 (55.4)		
Insurance, n (%)				0.017	0.023
EPO	525 (6.4)	547 (6.6)	566 (6.9)		
HMO	855 (10.4)	874 (10.6)	841 (10.2)		
IND	71 (0.9)	71 (0.9)	71 (0.9)		
OTH	2,758 (33.5)	2,759 (33.5)	2,711 (32.9)		
POS	3,317 (40.3)	3,264 (39.6)	3,328 (40.4)		
PPO	708 (8.6)	719 (8.7)	717 (8.7)		
Hospital bed size, n (%)				0.078	**0.329**
Small (<100)	3,373 (41.0)	3,152 (38.3)	3,852 (46.8)		
Medium (101–249)	1,592 (19.3)	1,496 (18.2)	1,226 (14.9)		
Large (>250)	1,368 (16.6)	1,517 (18.4)	636 (7.7)		
Unknown	1,901 (23.1)	2,069 (25.1)	2,520 (30.6)		

Bold text indicates significant effect size (SMD ≥0.2).

Separate models were created for rates of 30-day readmission, post-operative complications, ER visits, discharge status, LOS, total hospital charges, and out-of-pocket charges. Provider pRDI category II was associated with increased post-operative complications (OR 1.10; 95% CI 1–1.21), LOS (Coeff. 0.56; 95% CI 0.37–0.76), total hospital charges (Coeff. 47,700; 95% CI 40,200–55,300), and decreased reoperation (OR 0.6; 95% CI 0.41–0.99) and discharge to home (OR 0.76; 95% CI 0.70–0.82). Category III was associated with increased LOS (Coeff. 0.62;

Table 3
Multivariate regression models performed on matched cohort. Total $n = 17,291$.

	Dependent Variables				
	30-day Readmission	30-day Reoperation	30-day Complication	30-day ER visit	Discharge home
	Logistic	*Logistic*	*Logistic*	*Logistic*	*Logistic*
	OR (95% CI)	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*	*OR (95% CI)*
Category					
I (ref)					
II	0.99 (0.87, 1.13)	**0.64 (0.41, 0.99)***	**1.10 (1, 1.21)***	1.01 (0.87, 1.17)	**0.76 (0.70, 0.82)*****
III	0.95 (0.83, 1.08)	0.78 (0.52, 1.18)	0.92 (0.84, 1.02)	1.03 (0.89 1.19)	**0.90 (0.83, 0.97)****
Interaction: race*category					
White*II (ref)					
Asian*II	**0.39 (0.14, 0.96)***	2.6E-6 (1.14E-63, 1.4E-16	0.59 (0.28, 1.19)	1.01 (0.43, 2.35)	0.89 (0.51, 1.55)
Black*II	1.01 (0.63, 1.62)	0.94 (0.18, 4.12)	1.10 (0.78, 1.55)	0.78 (0.47, 1.30)	1.17 (0.87, 1.57)
Hispanic*II	1.21 (0.71, 2.08)	0.40 (0.06, 1.73)	1.30 (0.86, 1.99)	1.45 (0.82, 2.56)	0.81 (0.57, 1.14)
White*III (ref)					
Asian*III	0.73 (0.34, 1.56)	0.55 (0.02, 6.03)	0.84 (0.43, 1.61)	0.51 (0.19, 1.28)	0.82 (0.48, 1.38)
Black*III	1.44 (0.92, 2.26)	1.47 (0.41, 5.48)	0.96 (0.68, 1.37)	1.03 (0.63, 1.67)	**1.41 (1.05, 1.9)***
Hispanic*III	0.90 (0.51, 1.58)	0.33 (0.05, 1.40)	1.27 (0.83, 1.95)	0.98 (0.53, 1.79)	0.76 (0.54, 1.07)
Year of surgery, mean (SD)	**0.96 (0.94, 0.98)*****	0.99 (0.94, 1.05)	**0.9 (0.89, 0.91)*****	**0.70 (0.68, 0.72)*****	**0.96 (0.95, 0.97)*****
Age, years, mean (SD)	**1.02 (1.01, 1.02)*****	1.00 (0.98, 1.02)	**1.02 (1.02, 1.03)*****	1.00 (1.00, 1.01)	**0.96 (0.96, 0.97)*****
CCI	**1.15 (1.13, 1.16)*****	1.03 (0.97, 1.09)	**1.09 (1.08, 1.11)*****	**1.09 (1.06, 1.11)*****	**0.89 (0.88, 0.90)*****
Sex					
Female (ref)					
Male	1.04 (0.94, 1.14)	1.14 (0.83, 1.56)	0.94 (0.87, 1.01)	1.10 (0.99, 1.23)	**1.20 (1.13, 1.28)*****
Race					
White (ref)					
Asian	1.66 (0.95, 2.74)	2.02 (0.33, 6.62)	1.09 (0.67, 1.70)	**1.85 (0.99, 3.24)***	0.88 (0.60, 1.32)
Black	1.00 (0.70, 1.39)	1.49 (0.51, 3.42)	1.08 (0.83, 1.38)	1.19 (0.82, 1.67)	**0.67 (0.54, 0.83)*****
Hispanic	1.03 (0.68, 1.5)	**2.66 (1.16, 5.34)***	0.81 (0.59, 1.10)	1.11 (0.72, 1.64)	0.95 (0.74, 1.23)
Networth range					
>$500K					
<$25k	**1.23 (1.05, 1.45)***	0.66 (0.38, 1.15)	**1.19 (1.06, 1.34)****	**1.59 (1.33, 1.90)*****	1.00 (0.90, 1.10)
$25K-$149k	1.07 (0.91, 1.26)	1.18 (0.72, 1.91)	1.10 (0.98, 1.24)	1.14 (0.95, 1.36)	1.07 (0.97, 1.18)
$150K-$249k	1.11 (0.93, 1.33)	0.93 (0.51, 1.64)	0.99 (0.86, 1.13)	1.06 (0.86, 1.30)	0.97 (0.87, 1.08)
$250K-$499k	1.1 (0.95, 1.29)	0.99 (0.60, 1.61)	1.04 (0.93, 1.16)	1.10 (0.92, 1.31)	1.03 (0.94, 1.13)
Education level					
Bachelor's degree or greater (ref)					
High school diploma or less	0.99 (0.82, 1.18)	1.29 (0.71, 2.43)	0.88 (0.77, 1.01)	0.91 (0.74, 1.11)	**1.28 (1.15, 1.43)*****
Less than Bachelor's Degree	1.06 (0.91, 1.24)	1.46 (0.89, 2.51)	1.03 (0.92, 1.15)	1.07 (0.90, 1.27)	**1.11 (1.01, 1.21)***
Insurance type					
EPO (ref)		0.89 (0.45, 1.79)			
HMO	**1.45 (1.12, 1.89)****	2.02 (0.55, 5.98)	**1.26 (1.05, 1.53)***	**1.42 (1.11, 1.82)****	**0.48 (0.40, 0.57)*****
IND	0.68 (0.36, 1.20)	0.54 (0.28, 1.09)	0.96 (0.64, 1.40)	1.26 (0.74, 2.07)	0.85 (0.61, 1.19)
OTH	**1.37 (1.07, 1.78)***	0.69 (0.40, 1.26)	**1.34 (1.12, 1.61)****	1.25 (0.97, 1.61).	**0.43 (0.37, 0.50)*****
POS	0.93 (0.73, 1.18)	0.75 (0.35, 1.59)	1.11 (0.94, 1.31)	0.98 (0.79, 1.22)	0.97 (0.83, 1.13)
PPO	1.03 (0.78, 1.37)	0.89 (0.45, 1.79)	1.21 (0.99, 1.48)	1.27 (0.97, 1.66).	**0.43 (0.36, 0.51)*****
Bed size					
Large (ref)					
Small	**0.74 (0.62, 0.88)*****	1.25 (0.81, 1.88)	**0.81 (0.71, 0.91)*****	1.00 (0.83, 1.19)	**1.79 (1.61, 1.99)*****
Medium	0.98 (0.86, 1.12)	0.80 (0.45, 1.34)	1.04 (0.94, 1.15)	1.01 (0.86, 1.18)	**1.17 (1.07, 1.27)*****
Unknown	1.04 (0.93, 1.17)	1.05 (0.71, 1.55)	0.96 (0.88, 1.05)	0.99 (0.87, 1.13)	**0.92 (0.85, 0.99)***

Bold text indicates statistical significance.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

95% CI 0.43–0.81) and total hospital charges (Coeff. 36,800; 95% CI 29,200–44,400), with decreased discharge to home (OR 0.90; 95% CI 0.83–0.97). Asian race was associated with increased odds of ER visit (OR 1.85; 95% CI 0.99–3.2), while Black race was associated with decreased odds of discharge to home (OR 0.67; 95% CI 0.54–0.83) and increased LOS (Coeff. 0.70; 95% CI 0.16–1.25), as compared to White race. Hispanic race had significantly increased odds of reoperation compared to White race (OR 2.66; 95% CI 1.16–5.34). Patients with Asian race treated by category II providers had decreased odds of readmission (OR 0.38; 95% CI 0.14–0.96). Patients with Black race treated by category III providers had increased odds of discharge to home (OR 1.41; 95% CI 1.1–1.9).

Small hospital bed size was associated with decreased readmission (OR 0.74; 95% CI 0.62–0.88), post-operative complications (OR 0.81; 95% CI 0.71–0.91), LOS (Coeff. −1,72; 95% CI -1.95 to −1.49), and total hospital charges (Coeff. −42,600; 95% CI -51,600 to −33,600), and increased discharge to home (OR 1.79; 95% CI 1.61–1.99) compared to large hospital bed size. Medium hospital bed size was associated with increased discharge to home (OR 1.17; 95% CI 1.07–1.27) and decreased LOS (Coeff. −0.74; 95% CI -0.95 to −0.53).

To further understand the influence of provider pRDI on minority patients, we analyzed outcome trends for minority patients (Black,

Table 4
Multivariate regression models cont.

	Dependent Variables		
	Hospital Length of Stay	Total Hospital Charges	Out of pocket Charges
	Linear	*Linear*	*Linear*
	Coeff. (95% CI)	*Coeff. (95% CI)*	*Coeff. (95% CI)*
Category			
I (ref)			
II	**0.56 (0.37, 0.76)*****	**47,700 (40,200, 55,300)*****	**236.14 (151.00, 321.03)*****
III	**0.623 (0.43, 0.82)*****	**36,800 (29,200, 44,400)*****	**208.25 (123.00, 293.91)*****
Interaction: race*category			
White*II (ref)			
Asian*II	0.15 (−1.24, 1.54)	36,700 (−18,000, 91,500)	−216.70 (−832, 398.52)
Black*II	−0.18 (−0.94, 0.57)	−6,800 (−36,500, 22,900)	−116.58 (−451.00, 217.70)
Hispanic*II	0.48 (−0.34, 1.31)	1,050 (−31,500, 33,600)	28.948 (−337.00, 394.37)
White*III (ref)			
Asian*III	1.03 (−0.32, 2.37)	−2,247 (−55,200, 50,700)	−2.85 (−598.00, 592.35)
Black*III	−0.09 (−0.85, 0.66)	−12,810 (−42,400, 16,800)	−248.66 (−581.00, 84.08)
Hispanic*III	−0.02 (−0.84, 0.80)	14,180 (−18,100, 46,500)	−109.03 (−47, 254.09)
Year of surgery, mean (SD)	0.02 (−0.00, 0.05)	**9,880 (8,830, 10,900)*****	**31.27 (19.50, 43.02)*****
Age, years, mean (SD)	**0.01 (0.01, 0.02)*****	**−399 (-701.00, -97.90)****	**−9.15 (-12.50, -5.76)*****
CCI	**0.41 (0.38, 0.44)*****	**6,450 (5,250, 7,650)*****	**−17.10 (-30.60, -3.61)***
Sex			
Female (ref)			
Male	**0.26 (0.11, 0.41)*****	3,790 (−2,030, 9,610)	−3.97 (−69.40, 61.43)
Race			
White (ref)			
Asian	0.33 (−0.66, 1.31)	−6,920 (−45,700, 31,800)	102.47 (−333.00, 538.28)
Black	**0.70 (0.16, 1.25)***	3,030 (−18,300, 24,300)	118.27 (−121.00, 357.91)
Hispanic	0.12 (−0.46, 0.70)	20,600 (−2,270, 43,400)	22.81 (−234.00, 279.40)
Networth range			
>$500K			
<$25k	0.13 (−0.11, 0.38)	**−14,200 (-23,900, -4,560)****	**198.98 (90.40, 307.51)*****
$25K-$149k	−0.00 (−0.24, 0.24)	**−12,100 (-21,500, -2,650)***	**105.99 (0.13, 211.86)***
$150K-$249k	0.05 (−0.22, 0.32)	−7,850 (−18,500, 2,820)	86.85 (−33.10, 206.82)
$250K-$499k	−0.06 (−0.30, 0.17)	**−10,400 (-19,600, -1,210)***	−6.13 (−109.00, 97.14)
Education level			
Bachelor's degree or greater (ref)			
High school diploma or less	**−0.50(-0.76, -0.23)*****	**−20,100 (-30,500, -9,580)*****	15.98 (−102.00, 133.71)
Less than Bachelor's Degree	**−0.28 (-0.50, -0.06)***	**−11,200 (-19,900, -2,550)***	90.64 (−6.91, 188.19)
Insurance type			
EPO (ref)			
HMO	**0.40 (0.03, 0.77)***	−7,400 (−22,000, 7,220)	**−315.08 (-479.00, -150.74)*****
IND	−0.09 (−0.94, 0.76)	−27,900 (−61,300, 5,590)	**−658.51 (-1030.00, -282.58)*****
OTH	**0.38 (0.04, 0.72)***	6,620 (−6,900, 20,100)	**−389.95 (-542.00, -237.94)*****
POS	−0.05 (−0.36, 0.26)	174 (−11,900, 12,300)	−24.98 (−161.00, 111.04)
PPO	0.21 (−0.19, 0.60)	8,010 (−7,440, 23,500)	−60.99 (−235.00, 112.74)
Bed size			
Large (ref)			
Small	**−1.72 (-1.95, -1.49)*****	**−42,600 (-51,600, -33,600)*****	**140.86 (39.30, 242.41)****
Medium	**−0.74 (-0.95, -0.53)*****	5,160 (−3,060, 13,400)	−7.26 (−99.70, 85.22)
Unknown	**−0.29 (-0.47, -0.10)****	−4,450 (−11,600, 2,740)	**193.51 (113.00, 274.32)*****

Bold text indicates statistical significance.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Asian, Hispanic) with increasing provider category (Fig. 2A–H). Notably, increasing category showed a trend of increased rate of readmission, hospital LOS, and hospital charge; however, the rate of reoperation, discharge to home and ER visits trended downward with increasing provider category.

4. Discussion

To the best of our knowledge, this is the first analysis of the effect of patient-level factors including socioeconomic variables and provider exposure to diversity on cervical and lumbar fusion outcomes. As expected, we find worse outcomes in non-White patients and those in lower socioeconomic groups, consistent with prior studies.[7–10] What is most unique about our manuscript, however, is the inclusion of the provider patient racial diversity index and its effect on patient outcomes. Although these are small effects, we find that Asian patients who saw providers categorized into higher provider pRDI (category II) had decreased odds of readmission, and Black patients treated by providers in category III had increased odds of discharge to home. Taken together, these suggest potentially improved outcomes for some minority patients when cared for by a surgeon who serves a racially diverse patient population.

While past research has shown minority patients benefit from having minority physicians,[11,12] the physician workforce is marked by significant underrepresentation of several minority groups.[13] Few studies have investigated whether the diversity of providers' patient population and a provider's individual cultural sensitivity can positively impact patient outcomes. This is especially important in the field of neurosurgery, as it has a significantly lower representation of Black and Hispanic surgeons compared with many other surgical and medical specialties.[14–17] We employed the novel concept of the provider patient racial diversity index[4] in the setting of lumbar and cervical fusion patients to investigate the effect of provider-level factors on surgical outcomes. We found the

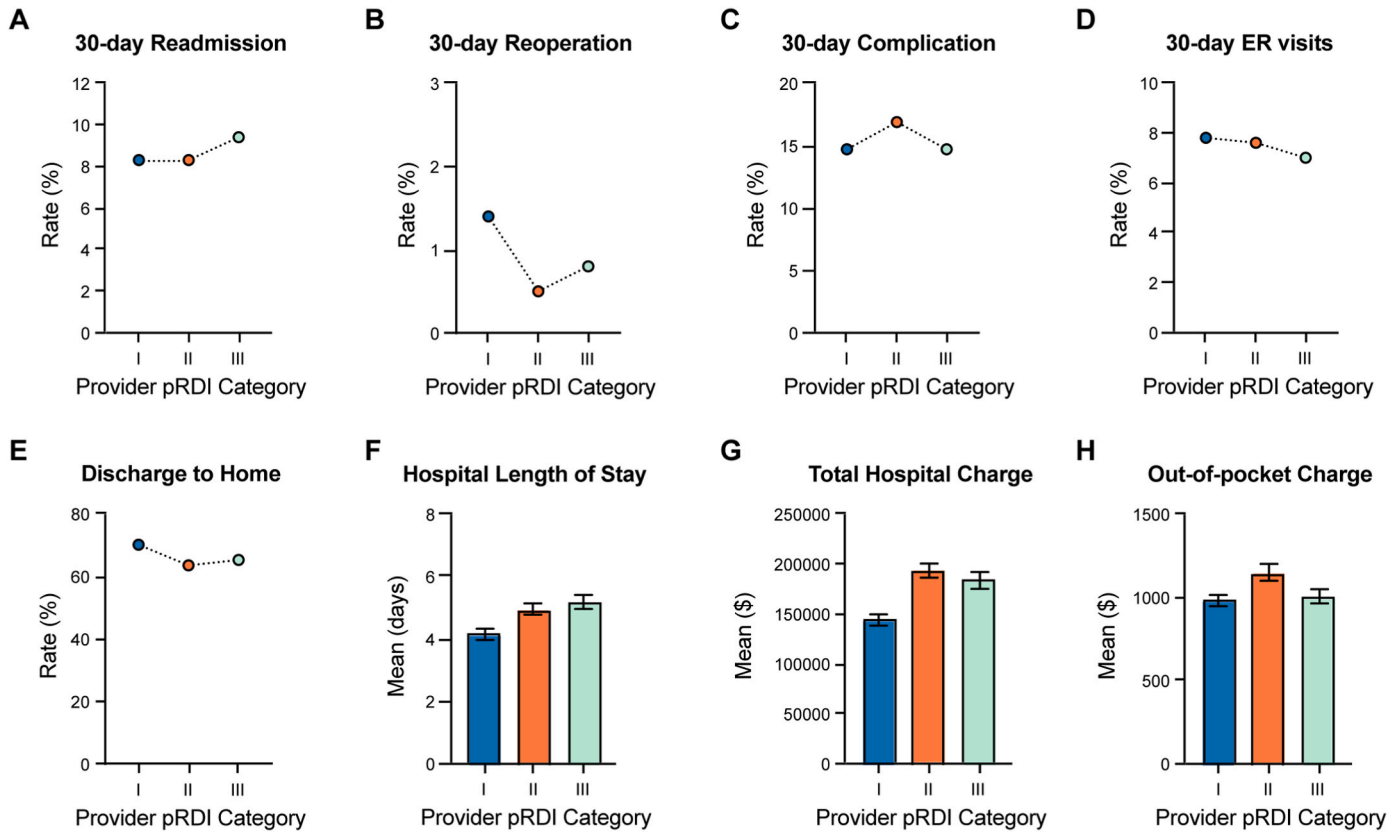

Fig. 2. Outcome trends across provider pRDI category among minority patients (Black, Asian, Hispanic) from the matched cohort for (A) 30-day readmission, (B) 30-day reoperation, (C) 30-day complication, (D) 30-day ER visits, (E) discharge to home, (F) hospital length of stay, (G) total hospital charges, and (H) out-of-pocket charges. Total $n = 3{,}187$.

highest mean provider pRDI in Hawaii, South Carolina, and Georgia. Of these states, Hawaii is the only majority-minority state,[18] indicating that the percentage of minority patients in a particular state may not be the best proxy for the diversity of a provider's patient population.

There is an implicit understanding that providing culturally appropriate care will improve quality of care, and cultural competence has gained attention from health policymakers and professionals as a strategy to improve patient healthcare outcomes.[19] Effective cultural competency in healthcare professionals has been associated with increased patient adherence to treatment and advice, increased patient satisfaction and perceived quality of care, more effective communication between providers and patients, and improved health outcomes.[20] While several studies have explored diversity in neurosurgery, few have investigated the impact of cultural competency in neurosurgery on patient outcomes. A recent study by Jin et al. found patients with central nervous system malignancies who are seen by providers who score highly on the provider patient racial diversity index receive supportive care earlier in their disease courses.[4]

In our study, we did not consistently observe better outcomes in all minority patients treated by high provider pRDI physicians. However, we did observe some small positive impacts of minority patients treated by providers with higher category provider pRDI. Specifically, Asian patients treated by category II providers had decreased rates of readmission, and Black patients treated by category III providers had increased discharge to home compared to those treated by category I providers. We may have failed to identify additional significant interactions due to the increased statistical power necessary to detect interactions, as compared to main effects.[21] Alternatively, the benefits resulting from spine surgeons who treat a greater proportion of minority patients may be more nuanced than has been suggested in other studies, or our methodology in using a large insurance database—in particular lacking qualitative outcome metrics (e.g., SF-36, EQ-5D, or ODI)—may not be the best suited for this research question. However, we should note that we selected this particular database (Optum) to study this research question, as it is the only database that we are aware of that provides granular socioeconomic data on patients, including education level, income, and home ownership.

This study has several important limitations. Retrospective analysis of administrative databases such as the CDM are limited by the quality of data available and may under-report postoperative complication rates and outcomes.[22] Selection bias and missing or miscoded data may significantly impact our findings and results. Due to limitations of the CDM, we were unable to differentiate between different types (MIS vs open) or number of levels of fusion surgery, which may confound our results. We also cannot obtain information on surgeon experience or complexity of case. Furthermore, some variables in the CDM database reply on self-report (e.g., education, net-worth) and others are incomplete (e.g., between 23 % and 31 % of patients had unknown numbers of bed size). The bed size is a particularly important confounder because a higher proportion of category III patients were treated in small hospitals compared to category I patients, which could impact our results if differences in care are influenced by hospital bed size. Another important limitation is that national databases report generic outcome measures such as length of stay, hospital discharge, and readmission rates, rather than patient-specific outcome measures such as NDI, ODI, SF-36, or PROMIS. While the latter outcome measures are better reflections of spine fusion outcomes, they are not available in administrative databases such as CDM. Our multivariable regression analyses tested many hypotheses and consequently some findings of statistical significance may be due to chance. If a Bonferroni correction is applied, our findings of interaction between race and pRDI category are no longer statistically significant, indicating these results are due to chance or that we lack

sufficient statistical power to detect interaction, as compared to main, effects.

We were also limited to the racial categorizations available in the CDM database, which does not include all racial groups defined by the U.S. census. The CDM database includes only patients who are privately insured and may not be generalizable to all patients in the United States. Patient-provider access is significantly limited bidirectionally by factors outside of provider control, including insurance coverage, which may obviously bias the racial diversity metric. Finally, it is certainly possible the racial diversity of a provider's patient population, reported in this and a prior study,[4] is not the best metric by which to assess provider's cultural competency and sensitivity. There is no widely-agreed upon or published metric by which to judge a provider's level of cultural and diversity competency/sensitivity, which likely reflects many factors including not only exposure to diverse patient populations (that we highlight here), but also formal diversity training, humility, languages spoken, and other personal life experiences that impact the way a provider interacts with diverse patients and which cannot be gleaned from any national database or website. We lack concrete information about a provider's true exposure to diversity outside of our limited metric, which limits the conclusions that can be drawn from this study and highlights an important need for future work.

Despite these limitations, our findings demonstrate associations between patient- and provider-level factors and postoperative outcomes in cervical and lumbar fusion surgery. We present evidence that a provider's patient racial diversity index is associated with postoperative spine outcomes. We acknowledge that our findings are mixed, likely reflecting the nuances involved in caring for diverse patient populations and the subtleties of "cultural competency". We hope that highlighting the interaction between patient- and provider-level SES factors will lead to system-level solutions to address disparities faced by cervical and lumbar fusion patients, including improved access to care and provider diversity training. Importantly, our findings highlight the importance of focusing on a provider's experience with treating patients from diverse backgrounds to decrease healthcare inequities. Future studies should expand on this work by examining metrics to more accurately assess a provider's cultural competency and its impact on spine patients' postoperative outcomes. There is also a need to assess the impact of such metrics on patient's reported quality of care and trust in the physician-patient relationship.

5. Conclusion

Our results corroborate past findings that patient-level socioeconomic factors including race/ethnicity and net-worth are associated with worse post-operative outcomes including rates of 30-day readmission, post-operative complications, ER visit, discharge status, and LOS in cervical and lumbar fusion patients. To the best of our knowledge, this is the first analysis of the association between surgeon's exposure to diversity and the outcomes of diverse spine fusion patients. Despite significant limitations, our study suggests that increased physician exposure to a diverse patient population may be important in reducing disparities in post-operative lumbar and cervical fusion outcomes.

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CRediT authorship contribution statement

Gavin Touponse: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Karen Malacon:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Guan Li:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Ezra Yoseph:** Writing – review & editing, Writing – original draft. **Summer Han:** Methodology, Supervision, Writing – review & editing. **Corinna Zygourakis:** Writing – review & editing, Supervision, Resources, Methodology, Conceptualization.

Declaration of competing interest

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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Appendix A. Supplementary data

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