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Socioeconomic disparities in lumbar fusion rates were exacerbated during the COVID-19 pandemic

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ABSTRACT

Background: The COVID-19 pandemic disrupted healthcare access and utilization throughout the US, with variable impact on patients of different socioeconomic status (SES) and race. We characterize pre-pandemic and pandemic demographic and SES trends of lumbar fusion patients in the US.

Methods: Adults undergoing first-time lumbar fusion 1/1/2004–3/31/2021 were assessed in Clinformatics® Data Mart for patient age, geographical location, gender, race, education level, net worth, and Charlson Comorbidity Index (CCI). Multivariable regression models were used to evaluate the significance of trends over time, with a focus on pandemic trends 2020–2021 versus previous trends 2004–2019.

Results: The total 217,204 patients underwent lumbar fusions, 1/1/2004–3/31/2021. The numbers and per capita rates of lumbar fusions increased 2004–2019 and decreased in 2020 (first year of COVID-19 pandemic), with large variation in geographic distribution. There was overall a significant decrease in proportion of White patients undergoing lumbar fusion over time (OR=0.997, p<.001), though they were more likely to undergo surgery during the pandemic (OR=1.016, p<.001). From 2004–2021, patients were more likely to be educated beyond high school. Additionally, patients in the highest (>$500k) and lowest (<$25k) net worth categories had significantly more fusions over time (p<.001). During the pandemic (2020–2021), patients in higher net worth groups were more likely to undergo lumbar fusions ($150k–249k & $250k–499k: p<.001) whereas patients in the lowest net worth group had decreased rate of surgeries (p<.001). Lastly, patients' CCI increased significantly from 2004 to 2021 (coefficient=0.124, p<.001), and this trend held true during the pandemic (coefficient=0.179, p<.001).

Conclusions: To the best of our knowledge, our work represents the most comprehensive and recent characterization of SES variables in lumbar fusion rates. Unsurprisingly, lumbar fusions decreased overall with the onset of the COVID-19 pandemic. Importantly, disparities in fusion patients across patient race and wealth widened during the pandemic, reversing years of progress, a lesson we can learn for future public health emergencies.

Introduction

There has been a significant increase in the number and rate of lumbar fusion surgeries performed worldwide and in the United States (US) over the last several decades [1,2]. Several studies suggest that socioeconomic status (SES), including race and ethnicity, have a significant impact on the delivery of orthopedic and, in particular, spine surgical care [3]. One study shows that Medicaid patients have lower rates of scheduling appointments for knee arthroplasty compared to Medicare and privately insured patients (30.1% vs 96% and 100%) [4]. A retrospective analysis of Nationwide Inpatient Sample and US Census data found significantly higher rates of surgery for lumbar spinal stenosis in

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White patients compared to Black and Hispanic patients (1.074/1000 vs 0.558/1000 and 0.339/1000, respectively) [5].

Recently published studies on surgical disparities in healthcare access during the COVID-19 pandemic present a mixed view. A national study on 767 hospitals assessing all payer types found that White patients experienced the greatest reduction in elective surgeries, compared to other racial groups, suggesting that the pandemic did not exacerbate racial disparities in elective surgical care [6]. Further studies in bariatric, cardiac, and orthopedic surgical subspecialties revealed that patient populations were more diverse (lessened racial and SES disparities) after the onset of the pandemic for some surgical procedures but less diverse (greater racial and SES disparities) for others [7–10]. Studies assessing academic general surgery departments, however, showed that male, White, and privately insured patients were more likely to undergo medically-necessary procedures during the pandemic [11] and that patients with higher SES (commercial or non-governmental insurance) were more likely to utilize both in-person and telemedicine visits during the pandemic [12].

The primary goal of our study is to investigate the most recent trends in lumbar fusion rates through the first year of the COVID-19 pandemic (defined as 2020–2021). In order to do this, we evaluate trends in the many years leading up to the pandemic (2004–2019) to analyze whether what occurred during the pandemic was a statistically significant disruption or continuation of prior trends. Our secondary goal is to investigate the unique SES variables, including education and net worth from Optum's de-identified Clinformatics® Data Mart (CDM) database [13], in order to better characterize the intersectionality of race with other SES variables and disparities in access to lumbar fusion care both before and during the COVID-19 pandemic.

Materials and methods

All adult patients undergoing first-time lumbar spinal fusion from January 1, 2004, through March 31, 2021, were identified via CPT codes (Supplementary Table 1) in CDM, a de-identified database derived from a large, adjudicated claims data warehouse containing commercial and Medicare US patient data. These CPT codes contain first-time single and multi-level spinal fusions, from either an anterior, anterolateral, posterior, or posterolateral approach, with or without laminectomy and discectomy. This included both trauma and elective cases. We excluded patients undergoing surgery in the ambulatory/outpatient setting and revision surgeries.

The Inpatient, Medical Claims, Medical Enrollment, Provider, and Provider Bridge tables within the Socioeconomic Status dataset were used to collect the following variables for each patient: age, gender, race (Asian, Black, Hispanic, White, and unknown), education (less than high school, high school, less than bachelor's degree, bachelor's degree or more, and unknown), household net worth (less than $25,000, $25,000–149,000, $150,000–249,000, $250,000–499,000, $500,000 or more), Charlson Comorbidity Index (CCI; calculated using ICD-9/10 codes at the time of procedure, listed in Supplementary Table 2), and provider's practice location by state at the time of the lumbar fusion claim. The categories for race (Asian, Black, Hispanic, White, and unknown), education (less than high school, high school, less than bachelor's degree, bachelor's degree or more, and unknown), and net worth (less than $25,000, $25,000–149,000, $150,000–249,000, $250,000–499,000, and $500,000 or more) were set by the database. Patient demographic data such as race were elicited from beneficiaries at the time of enrollment. Net worth was not explicitly solicited from the beneficiary; instead, this was determined by linking beneficiaries' health information to an external commercial data vendor in a proprietary manner [14–17]. Gross case counts by state were collected and visualized in graphs and maps using Microsoft® Excel® for Microsoft 365 MSO. State populations were collected annually from January 1, 2004, through July 1, 2021, according to available data from the US Census Bureau [18–20].

Table 1
Demographic characteristics of U.S. lumbar fusion patients, 2004–2021, total n=217,204.

Age (mean [SD])	60.21 (13.74)
Charlson Comorbidity Index (mean [SD])	2.55 (2.67)
Gender	
Female	119,158 (54.9%)
Male	98,025 (45.1%)
Unknown	21 (0.0%)
Race	
Asian	3476 (1.6%)
Black	21,541 (9.9%)
Hispanic	16,016 (7.4%)
White	17,1372 (78.9%)
Unknown	4799 (2.2%)
Education	
Less than high school	754 (0.3%)
High school	61,624 (28.4%)
Less than bachelor's degree	121,534 (56.0%)
Bachelor's degree or more	32,664 (15.0%)
Unknown	628 (0.3%)
Net worth	
Less than $25,000	45,577 (21.0%)
$25,000–$149,000	40,785 (18.8%)
$150,000–$249,000	23,404 (10.8%)
$250,000–$499,000	37,515 (17.3%)
$500,000 and greater	55,283 (25.5%)
Unknown	14,640 (6.7%)

SD = standard deviation.

The COVID-19 pandemic was defined as the years 2020 and 2021. This study was approved by our Institutional Review Board (IRB #40,974).

Multivariable linear and logistic regression models were performed using R statistical programming language version 4.1. Regression results were reported using the stargazer package [21]. The outcomes of each regression model are labeled as the title of each regression model table while the variables listed within the tables themselves are the corresponding independent variables or inputs for each regression model (Tables 2–6). Logistic regression was performed for each categorical outcome variable (Tables 2–5), while linear regression was performed for the numerical outcome variable (CCI, Table 6). "Year of fusion" includes the whole time period analyzed, 2004–2021, while "during COVID-19 pandemic" assesses 2020–2021.

Results

Demographic characteristics

217,204 patients underwent lumbar spinal fusions from January 1, 2004, to March 31, 2021. 54.9% were female, and the mean age was 60.21±13.74 years old. 78.9% of patients self-identified as White, 9.9% Black, 7.4% Hispanic, and 1.6% Asian. The majority of patients' educational status was "less than a bachelor's degree" (56.0%). 28.4% were high school graduates, while 15.0% had a bachelor's degree or greater. The net worth distribution among lumbar fusion patients included 25.5% of patients in the highest net worth group (>$500k) and 21.0% in the lowest net worth group (<$25k). The mean CCI was 2.55 (Table 1).

Number and rate of surgeries

The number (Fig. 1A) and per capita rate (Fig. 1B) of lumbar fusion surgeries increased from 2004 through 2019 and decreased in 2020, the first year of the COVID-19 pandemic. The distribution of lumbar fusion surgeries varied widely across the US during this time period (2004–2021). The least number of lumbar fusions (summed across all pre-pandemic years, 2004 to 2019) were performed in Alaska (48), Vermont (127), Montana (189), Delaware (182), and West Virginia (178), while the greatest number of surgeries were performed in Texas

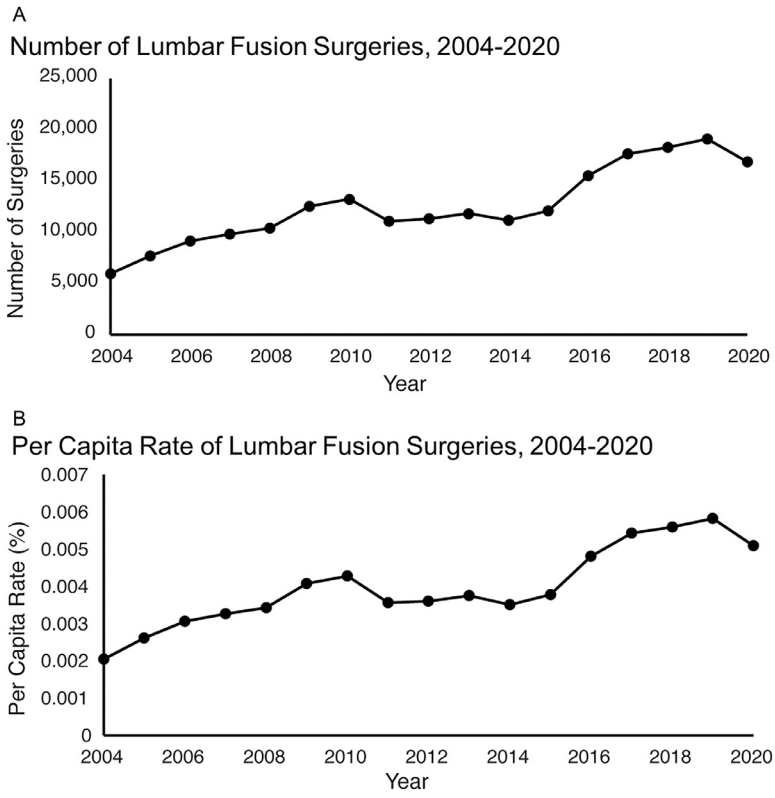

Fig. 1. Number (A) and per capita rate (B) of lumbar spinal fusion surgeries performed in the US, 2004–2020.

(23,446), Florida (20,410), Georgia (13,059), California (10,594), and Ohio (10,645) (Fig. 2A and Supplementary Table 3). Per capita rates of lumbar fusion by state (rate per year, averaged across 2004–2019) were lowest in Alaska (4.174E-6%), West Virginia (6.088E-6%), Michigan (9.452E-6%), Hawaii (9.687E-6%), and Pennsylvania (1.031E-5%). The highest per capita rates were in Colorado (1.089E-4%), Rhode Island (1.087E-4%), Minnesota (9.393E-5%), Washington D.C. (9.384E-5%), and Georgia (8.252E-5%) (Fig. 2B and Supplementary Table 4).

During the first year of the pandemic (2020), the geographic distribution of number of total surgeries remained relatively stable, with states like Texas and Florida still having the greatest number of lumbar fusions (Fig. 2C). The per capita distribution shows that a few states (e.g., Minnesota, South Carolina) appeared to be more heavily impacted during this time period (Fig. 2D).

Demographic and socioeconomic trends over time

Throughout the entire study period (from 2004 to 2021), there was a steady decrease in the proportion of White patients and, conversely, an increase in proportion of Asian and Hispanic patients undergoing lumbar fusion (Fig. 3B). There was a trend towards fewer proportion of patients with less than a high school degree undergoing lumbar fusions during this time period (Fig. 3C). Patients in the lowest (<$25k) and highest (>$500k) net worth groups were more likely to undergo lumbar fusions over time (Fig. 3D). There was also an increase in patients with higher CCI undergoing surgery (Fig. 3E).

Multivariable regression models

We performed multivariable regression to adjust for confounders and further analyze these overall and pandemic-specific trends. There were no statistically significant trends for patient gender during the COVID-19 pandemic (2020–2021) compared to before the pandemic (2004–2019). There was an overall decrease from 2004 to 2021 in the number of females (odds ratio (OR)=0.994, p<.001) and increase in the number of males (1.006, p<.001) undergoing lumbar fusion (Table 2).

Our multivariable regression model for race (Table 3) shows a statistically significant increase in the number of self-identified Asian and Hispanic patients undergoing lumbar fusion between 2004 and 2021 (1.001 and 1.0034, respectively; both p<.001) with a corresponding decrease in the number of White patients undergoing lumbar fusion over time (0.997, p<.001). However, during the pandemic (2020–2021), White patients were more likely to undergo surgery (1.016, p<.001), whereas Asian and Hispanic patients were less likely to do so (0.997 and 0.986, respectively; p<.05 and p<.001, respectively).

Our multivariable model for education status (Table 4) shows that patients who were educated beyond high school ("less than a bachelor's degree" and "bachelor's degree or more") made up an increasing proportion of all lumbar fusion patients from 2004 to 2021. During the pandemic (compared to pre-pandemic, 2004–2019), patients with a high school diploma made up a larger proportion of those undergoing lumbar fusions (OR=1.009, p<.01) than those with education beyond high school, as well as without a high school diploma.

Our multivariable regression model for net worth (Table 5) showed statistically significant increases in proportions of lumbar fusions for patients in the highest and lowest net worth groups over time, with a decrease in proportion of patients with a net worth between $150k–499k (all p<.001). During the pandemic, patients in the three highest net worth groups made up increased proportions of lumbar fusion patients (≥$500k: p<.05; $150k–249k & $250k–499k: p<.001) whereas patients in the lowest net worth group (<$25k) had decreased rate of surgeries (p<.001).

Finally, our multivariable regression model for CCI (Table 6) showed that the CCI of patients undergoing lumbar fusions increased significantly from 2004 to 2021 (coefficient=0.124, p<.001). Patients with higher CCI were more likely to undergo lumbar fusion during the pandemic (0.179, p<.001; Table 6).

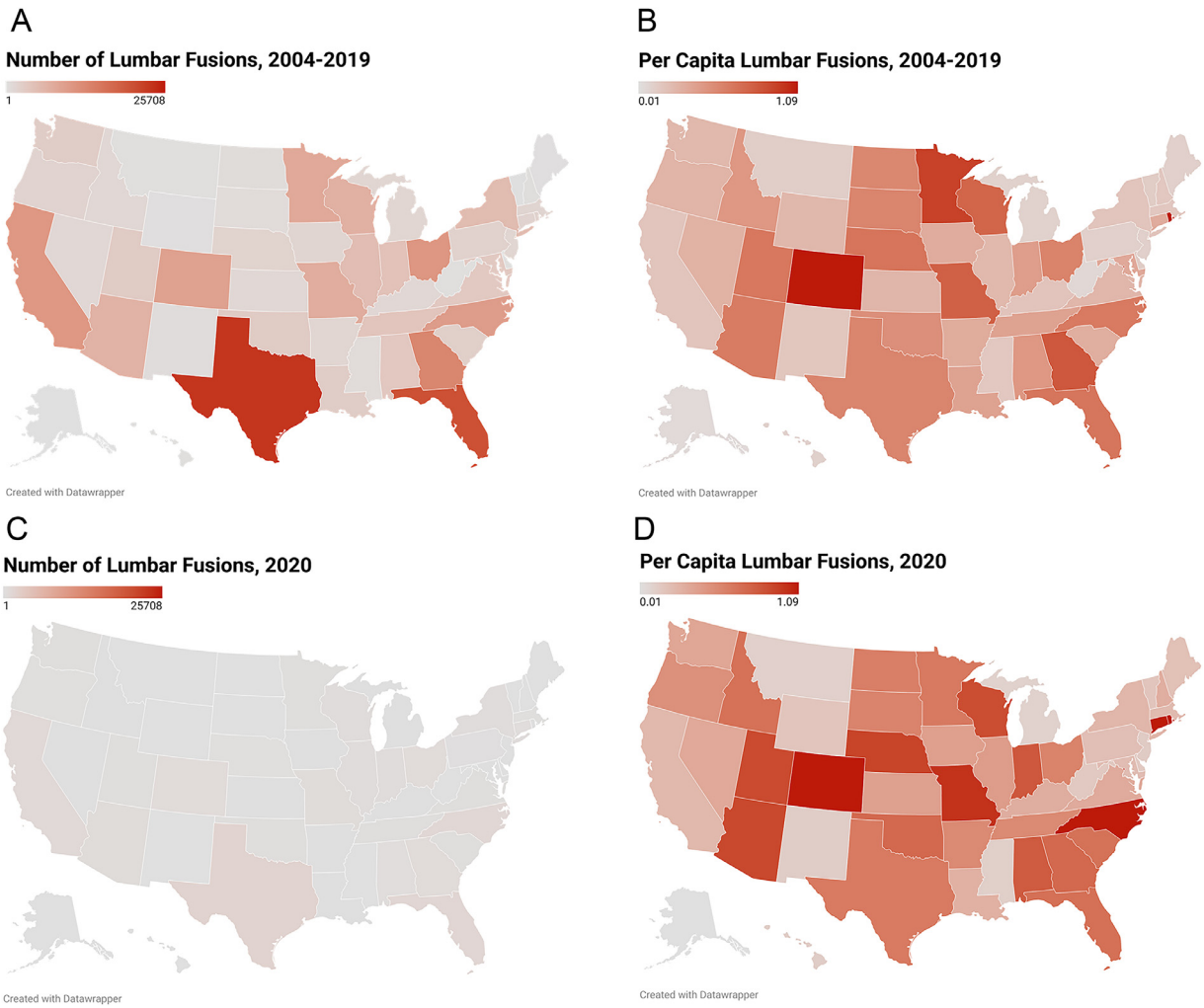

Fig. 2. Geographic distribution of lumbar spinal fusion surgeries performed in the United States. (A) State-level distribution of total number of lumbar spinal fusions in CDM population, summed across 2004–2019. (B) Per capita rate of lumbar spinal fusions by state, cumulative from 2004 to 2019. Note that all per capita rates were multiplied by 1E4 to allow software to create the choropleth heatmap. (C) State-level distribution during the COVID-19 pandemic of total number of lumbar spinal fusions in CDM population. (D) Per capita rate of lumbar spinal fusions by state during the COVID-19 pandemic. Note that all per capita rates were multiplied by 1E4 to allow software to create the choropleth heatmap.

Discussion

To the best of our knowledge, our work represents the most comprehensive and recent characterization of socioeconomic variables in lumbar fusion rates, including importantly during the COVID-19 pandemic. Similar to prior studies, we show an increase in lumbar fusion rates in this national CDM patient population from 2004 up to 2019, followed by an unsurprising decrease in 2020 (onset of the COVID-19 pandemic) [1,2,22–25]. This is likely due to the drastic decrease in elective surgeries in the early months of the pandemic, although emergency procedures remained unchanged, per Arnold et al. [26]. This decrease was also reflected in the Google search volume for terms related to elective spine surgery (a measure of public interest), which decreased dramatically at the start of pandemic-initiated restrictions and had yet to return to pre-pandemic levels by the end of 2020 [27]. Given that the rate of lumbar fusion surgery had steadily increased pre-pandemic, we cannot speculate on whether this is a temporary disruption or will represent a sustained plateau of lumbar spinal fusion rates in the years to come.

Importantly, disparities in lumbar fusion surgery across race and socioeconomic status widened during the COVID-19 pandemic. In particular, the prior trend (2004–2019) of increasing proportions of non-White and poorer patients undergoing lumbar fusions was reversed during the first year of the COVID-19 pandemic (2020–2021); there was a statistically significant increase in the proportion of White patients (as compared to Hispanic or Asian patients) undergoing lumbar fusions during 2020–2021. In addition, wealthier patients made up an increased proportion of lumbar fusion patients, while poor patients made up a decreased proportion of lumbar fusion patients during the pandemic (2020–2021, compared to 2004–2019). Our results are consistent with other published studies showing that the COVID-19 pandemic induced health care delays which disproportionally impacted lower SES patients [28] and that higher SES general surgery patients were more likely to utilize both in-person and telemedicine visits, as well as receive medically-necessary surgeries during the pandemic [11,12]. The onset of the pandemic was also associated with greater reduction in cancer screenings and cancer care utilization for racial minority and lower SES groups as compared to White, urban, and wealthier patients [29–31].

As for overall trends from 2004 to 2021, similar to previous studies, we found significant geographic variation at the state level in both total lumbar fusions and per capita fusions. We assessed per capita rates by using US Census data as our denominator (rather than number of Optum beneficiaries), which likely underestimates the true per capita rates of lumbar fusions. We still believe this provides useful comparative statistics for trend analysis, although reported differences may also reflect

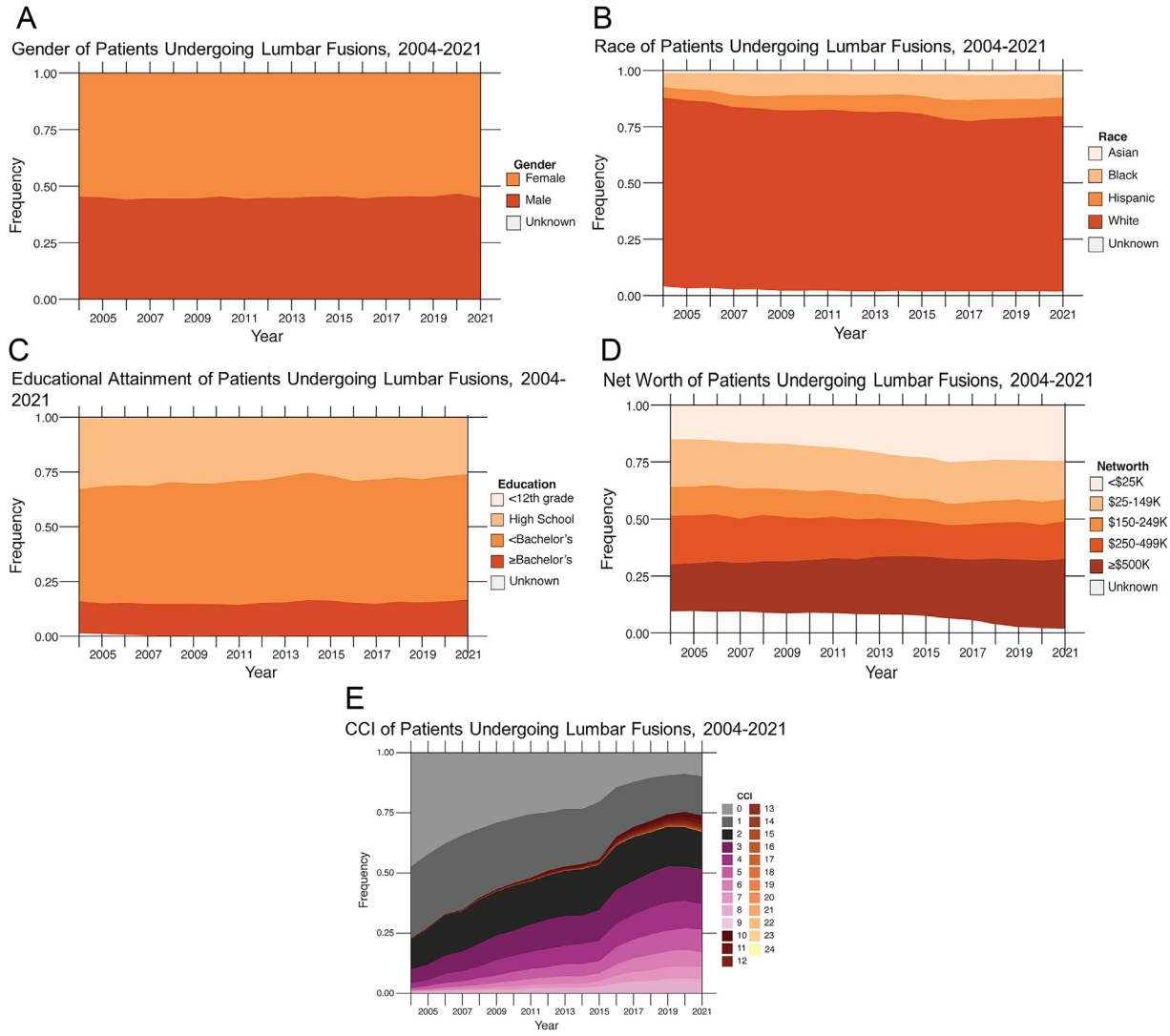

Fig. 3. Trends of lumbar fusion patient demographics, from 2004 to 2021. (A) Gender of lumbar spinal fusion patients per year of surgery; (B) race of lumbar spinal fusion patients per year of surgery; (C) education status of lumbar spinal fusion patients per year of surgery; (D) net worth of lumbar spinal fusion patients per year of surgery; (E) Charlson Comorbidity Index (CCI) of lumbar spinal fusion patients per year of surgery.

state-to-state differences in commercial insurance coverage. Our findings of low surgery rates within Hawaii and the Northeast (except for Rhode Island) are consistent with those from a 2001 US. Medicare spine surgery study [32]. Our higher rates of lumbar fusion in the South and Midwest, as well as specifically Colorado, and lowest rates in the Northeast are consistent with prior published geographical trends [32–36]. As expected, the geographic variation during the COVID-19 pandemic likely reflects the rapidly changing infection rates and hospital policies in different regions of the U.S. during this challenging period in time.

We found statistically significant increases in the proportions of Asian and Hispanic patients and a decreased proportion of White patients undergoing lumbar fusion from 2004 to 2021. These findings are consistent with prior studies showing an increase in Black and Hispanic patients, relative to white patients, undergoing lumbar spinal surgery between 2006 and 2014, with the most drastic changes occurring after passage of the Affordable Care Act in 2010 [37]. This decrease in racial disparity in lumbar surgery appears to be recent, as earlier studies did not find reductions in racial disparities in lumbar fusion across White and Black/Hispanic patients between 1989 and 2000 [38], 2000–2009 [5] or within 2016 [39]. Our results are also consistent with other studies showing an increase in racial minority patients undergoing anterior cervical spine surgery [40]. However, other studies have noted persistent disparities in the utilization of adult spinal deformity surgery across patient race [41]. Importantly, while there have been increases in racial minority patient undergoing lumbar fusions in our dataset, minority patients still remain significantly under-represented in this surgical population compared to the U.S. population as a whole. A recently published study showed that Hispanic and Asian/Pacific Islander patients from 2012 to 2015 received elective spinal fusions at a lower rate than White patients with similar diagnoses [42]. As of 2020–2021, our data show that 77.4% of lumbar fusion patients are white (compared to 60.1% of the overall U.S. population), 8.1% are Hispanic (compared to 18.2%), 10.8% are Black (compared to 12.6%) and 1.8% are Asian (compared to 5.6%) [43]. Minority patients therefore remain significantly under-represented in the lumbar fusion patient population.

Our analysis also revealed that disparities in lumbar fusion surgery have widened over the 2004–2021 timeframe between patients with high versus low educational attainment. Specifically, we note that patients without a high school diploma were less likely to undergo lumbar fusions over time. While prior studies have shown patients with low education levels have worse outcomes after elective lumbar surgery, our findings suggest they may also face challenges in accessing these procedures [44]. There is insufficient data for us to speculate on whether this is due to higher prevalence of manual labor jobs in those with lower

Table 2
Gender regression model.

	Odds ratio (95% confidence interval)	
	Female	Male
Year of fusion (2004–2021)	0.994*** (0.992, 0.997)	1.006 *** (1.003, 1.008)
During COVID-19 pandemic (2020–2021)	0.990 (0.958, 1.023)	1.010 (0.978, 1.044)
Age	1.010*** (1.010, 1.011)	0.990*** (0.989, 0.991)
Race		
White	Reference	Reference
Asian	1.008 (0.942, 1.079)	0.993 (0.928, 1.063)
Black	1.221*** (1.185, 1.258)	0.819*** (0.794, 0.844)
Hispanic	1.017 (0.983, 1.051)	0.984 (0.952, 1.017)
Unknown	0.954 (0.900, 1.010)	1.048 (0.989, 1.111)
Education		
Less than high school	0.804** (0.694, 0.933)	1.244** (1.072, 1.442)
High school	0.859*** (0.833, 0.887)	1.164*** (1.128, 1.201)
Less than bachelor's degree	0.982 (0.957, 1.008)	1.018 (0.992, 1.046)
Bachelor's degree or more	Reference	Reference
Unknown	0.862 (0.735, 1.013)	1.160 (0.988, 1.362)
Net worth		
Less than $25k	1.869*** (1.815, 1.925)	0.535*** (0.520, 0.551)
$25k–149k	1.342*** (1.304, 1.381)	0.745*** (0.724, 0.767)
$150k–249k	1.173*** (1.135, 1.211)	0.853*** (0.826, 0.881)
$250k–499k	1.137*** (1.106, 1.169)	0.880*** (0.856, 0.904)
$500k or greater	Reference	Reference
Unknown	1.302*** (1.252, 1.353)	0.768*** (0.739, 0.798)
CCI	0.947*** (0.944, 0.951)	1.055*** (1.052, 1.059)

Note:
*p<.05.
** p<.01.
*** p<.001.

Table 3
Race regression model.

	Odds ratio (95% confidence interval)			
	Asian	Black	Hispanic	White
Year of fusion (2004–2021)	1.001*** (1.000, 1.001)	1.000* (1.000, 1.001)	1.003*** (1.003, 1.004)	0.997*** (0.996, 0.997)
During COVID-19 pandemic (2020–2021)	0.997* (0.995, 0.999)	0.997 (0.992, 1.001)	0.986*** (0.982, 0.990)	1.016*** (1.010, 1.023)
Age	1.000 (1.000, 1.000)	1.000*** (1.000, 1.001)	0.999*** (0.999, 0.999)	1.000* (1.000, 1.000)
Gender				
Male	Reference	Reference	Reference	Reference
Female	1.000 (0.999, 1.001)	1.017*** (1.014, 1.019)	1.000 (0.997, 1.002)	0.986*** (0.982, 0.989)
Unknown	0.979 (0.928, 1.033)	1.135* (1.002, 1.285)	0.939 (0.841, 1.048)	0.939 (0.792, 1.114)
Education				
Less than high school	1.005 (0.996, 1.014)	0.963*** (0.943, 0.983)	1.679*** (1.648, 1.711)	0.622*** (0.605, 0.641)
High school	0.988*** (0.987, 0.990)	1.061*** (1.056, 1.066)	1.049*** (1.044, 1.053)	0.919*** (0.914, 0.925)
Less than bachelor's degree	0.990*** (0.989, 0.992)	1.011*** (1.007, 1.014)	1.015*** (1.012, 1.019)	0.990*** (0.985, 0.996)
Bachelor's degree or more	Reference	Reference	Reference	Reference
Unknown	0.992 (0.982, 1.002)	0.985 (0.963, 1.008)	1.007 (0.986, 1.028)	1.013 (0.982, 1.046)
Net worth				
Less than $25k	0.986*** (0.984, 0.988)	1.168*** (1.163, 1.173)	1.014*** (1.011, 1.018)	0.862*** (0.857, 0.867)
$25k–149k	0.987*** (0.985, 0.989)	1.071*** (1.067, 1.076)	1.010*** (1.006, 1.013)	0.941*** (0.936, 0.946)
$150k–249k	0.990*** (0.988, 0.992)	1.040*** (1.035, 1.044)	1.002 (0.998, 1.007)	0.971*** (0.965, 0.977)
$250k–499k	0.991*** (0.989, 0.992)	1.021*** (1.017, 1.025)	1.001 (0.998, 1.005)	0.987*** (0.982, 0.993)
$500k or greater	Reference	Reference	Reference	Reference
Unknown	0.995*** (0.992, 0.997)	1.069*** (1.063, 1.075)	1.033*** (1.028, 1.038)	0.906*** (0.899, 0.913)
CCI	1.000 (1.000, 1.000)	1.005*** (1.004, 1.006)	1.002*** (1.002, 1.003)	0.993*** (0.992, 0.993)

Note:
* p<.05.**p<.01.
*** p<.001.

educational attainment leading to lumbar fusion surgery. To the best of our knowledge, this is the first report of the effect of education level on lumbar fusion utilization rates. These findings are consistent with studies on other surgical procedures showing that patients with less than a bachelor's degree disproportionately lacked access to emergency general surgery [45] and lung transplantation [46]. However, other studies have reported improved recent access to glioblastoma multiforme surgery for low-education patients, indicating varying trends across different surgical procedures [47].

Our data also reveal increasing rates of lumbar fusions in patients in the highest and lowest net worth groups over time. In contrast, lumbar fusions decreased for patients with a net worth in the upper-middle categories ($150k–$499k). Part of this trend may be accounted for by the negative impacts of the Affordable Care Act on middle-class patients, who did not qualify for ACA tax credits and have faced increasingly expensive Marketplace insurance premiums since 2015 [48], though further study is needed to confirm this conjecture.

Finally, we found a significant increase over time in comorbidity burden of patients undergoing lumbar fusions. One contributing factor may be that comorbidities are compiled over time; thus, the increased CCI may reflect the increasing number of years for patient comorbidity reporting in CDM (regardless of patient age) or upcoding that has in-

Table 4
Education regression model.

	Odds ratio (95% confidence interval)			
	Less than high school	High school	Less than bachelor's degree	Bachelor's degree or more
Year of fusion (2004–2021)	1.000*** (1.000, 1.000)	0.994*** (0.994, 0.995)	1.005*** (1.004, 1.005)	1.002*** (1.002, 1.002)
During COVID-19 pandemic (2020–2021)	1.000 (0.999, 1.001)	1.009** (1.002, 1.016)	0.990* (0.982, 0.998)	0.999 (0.994, 1.005)
Age	1.000*** (1.000, 1.000)	1.001*** (1.001, 1.002)	1.000 (1.000, 1.000)	0.998*** (0.998, 0.999)
Gender				
Male	Reference	Reference	Reference	Reference
Female	1.000 (0.999, 1.000)	0.978*** (0.974, 0.981)	1.019*** (1.015, 1.023)	1.004** (1.002, 1.007)
Unknown	0.998 (0.974, 1.024)	0.970 (0.813, 1.157)	0.982 (0.796, 1.210)	1.056 (0.919, 1.214)
Race				
White	Reference	Reference	Reference	Reference
Asian	1.005*** (1.003, 1.007)	0.980** (0.967, 0.994)	0.952*** (0.937, 0.968)	1.066*** (1.054, 1.077)
Black	1.000 (0.999, 1.001)	1.116*** (1.110, 1.123)	0.921*** (0.914, 0.927)	0.975*** (0.970, 0.979)
Hispanic	1.025*** (1.024, 1.026)	1.092*** (1.084, 1.099)	0.927*** (0.919, 0.934)	0.965*** (0.960, 0.970)
Unknown	1.001 (1.000, 1.003)	0.974*** (0.962, 0.985)	0.992 (0.978, 1.006)	1.032*** (1.023, 1.042)
Net worth				
Less than $25k	1.006*** (1.005, 1.007)	1.584*** (1.575, 1.592)	0.907*** (0.901, 0.917)	0.691*** (0.688, 0.694)
$25k–149k	1.004*** (1.004, 1.005)	1.422*** (1.414, 1.429)	0.995 (0.989, 1.002)	0.701*** (0.698, 0.704)
$150k–249k	1.002*** (1.001, 1.003)	1.288*** (1.280, 1.297)	1.072*** (1.064, 1.080)	0.721*** (0.717, 0.724)
$250k–499k	1.001 (1.000, 1.001)	1.141*** (1.135, 1.147)	1.154*** (1.147, 1.161)	0.759*** (0.756, 0.762)
$500k or greater	Reference	Reference	Reference	Reference
Unknown	1.004*** (1.003, 1.005)	1.310*** (1.300, 1.320)	0.988* (0.979, 0.997)	0.757*** (0.752, 0.761)
CCI	1.000*** (1.000, 1.000)	1.004*** (1.004, 1.005)	0.999** (0999, 0.999)	0.997*** (0.996, 0997)

Note:
* p<.05.
** p<.01.
*** p<.001.

Table 5
Net worth regression model.

	Odds ratio (95% confidence interval)				
	Less than $25k	$25k–149k	$150k–249k	$250k–499k	$5000k or greater
Year of fusion (2004–2021)	1.010*** (1.010, 1.011)	1.000* (0.999, 1.000)	0.997*** (0.997, 0.998)	0.994*** (0.994, 0.995)	1.002*** (1.001, 1.002)
During COVID-19 pandemic (2020–2021)	0.980*** (0.974, 0.986)	1.005 (0.999, 1.011)	1.011*** (1.006, 1.016)	1.017*** (1.011, 1.024)	1.008* (1.001, 1.014)
Age	0.995*** (0.995, 0.996)	0.998*** (0.998, 0.998)	1.000*** (1.000, 1.001)	1.002*** (1.002, 1.002)	1.005*** (1.005, 1.005)
Gender					
Male	Reference	Reference	Reference	Reference	Reference
Female	1.065*** (1.061, 1.068)	1.003 (0.999, 1.006)	0.990*** (0.988, 0.993)	0.985*** (0.981, 0.988)	0.961*** (0.958, 0.964)
Unknown	0.917 (0.781, 1.078)	0.988 (0.839, 1.165)	0.943 (0.827, 1.076)	0.911 (0.777, 1.068)	1.186* (1.008, 1.395)
Race					
White	Reference	Reference	Reference	Reference	Reference
Asian	0.967*** (0.954, 0.979)	0.960*** (0.948, 0.972)	0.988* (0.978, 0.998)	0.980** (0.968, 0.992)	1.093*** (1.079, 1.107)
Black	1.216*** (1.210, 1.223)	1.003 (0.997, 1.008)	0.972*** (0.968, 0.977)	0.936*** (0.931, 0.941)	0.895*** (0.890, 0.990)
Hispanic	1.040*** (1.034, 1.046)	1.002 (0.996, 1.009)	0.988*** (0.983, 0.993)	0.977*** (0.971, 0.983)	0.969*** (0.963, 0.975)
Unknown	0.980*** (0.969, 0.991)	0.981*** (0.971, 0.992)	1.000 (0.991, 1.009)	1.010 (0.999, 1.020)	1.003 (0.992, 1.014)
Education					
Less than high school	1.412*** (1.373, 1.451)	1.271*** (1.236, 1.307)	1.037** (1.014, 1.060)	0.946*** (0.921, 0.972)	0.549*** (0.534, 0.565)
High school	1.359*** (1.352, 1.366)	1.235*** (1.229, 1.242)	1.075*** (1.071, 1.080)	0.988*** (0.983, 0.993)	0.552*** (0.549, 0.554)
Less than bachelor's degree	1.120*** (1.115, 1.126)	1.136*** (1.130, 1.141)	1.075*** (1.071, 1.079)	1.086*** (1.081, 1.091)	0.668*** (0.665, 0.672)
Bachelor's degree or more	Reference	Reference	Reference	Reference	Reference
Unknown	1.108*** (1.075, 1.141)	1.182*** (1.147, 1.219)	1.080*** (1.054, 1.106)	0.923*** (0.896, 0.950)	0.549*** (0.533, 0.566)
CCI	1.010*** (1.010, 1.011)	1.001*** (1.001, 1.002)	0.999* (0.999, 1.000)	0.997*** (0.997, 0.998)	0.990*** (0.989, 0.991)

Note:
* p<.05.
** p<.01.
*** p<.001.

creased at hospitals nationwide to enhance reimbursement, rather than worse overall health within the patient population. Another possibility is that healthier patients are having fusions in the outpatient setting, which were not captured in this analysis of inpatient fusions. Yet another explanation is that management of co-morbidities has improved such that surgeons are more comfortable providing fusions to patients with higher CCI, as has been shown in multiple other spine studies where there is a trend to operate on sicker patients over time [49–51].

A previous retrospective database study on lumbar fusions determined that patients who lived in higher Area Deprivation Index (ADI) neighborhoods had increased rates of post-operative complications and outcomes, including respiratory failure, ED visit within 90 days, and overall 90-day healthcare expenditures [52]. In New York state, a retrospective analysis on cervical fusion patients showed that African American patients had higher post-operative infection and bleeding rates compared to Caucasian patients [53]. Patients on Medicaid also had increased post-operative bleeding rates, in addition to increase in-hospital mortality [53]. In an all-encompassing literature review on associations between patient SES and spine surgery outcomes, several additional studies reported that Black patients have longer hospital lengths of stay, higher in-hospital mortality, and higher post-operative readmissions [54]. Additionally, higher educational attainment is associated

Table 6
CCI regression model.

	Coefficient (95% confidence interval)
Year of fusion (2004–2021)	0.124*** (0.122, 0.127)
During COVID-19 pandemic (2020–2021)	0.179*** (0.140, 0.218)
Age	0.055*** (0.055, 0.056)
Gender	
Male	Reference
Female	−0.313*** (−0.334, −0.293)
Unknown	0.859 (−0.171, 1.888)
Race	
White	Reference
Asian	0.125*** (0.044, 0.206)
Black	0.372*** (0.337, 0.407)
Hispanic	0.259*** (0.220, 0.299)
Unknown	0.023 (−0.046, 0.092)
Education	
Less than high school	0.629*** (0.453, 0.805)
High school	0.293*** (0.255, 0.330)
Less than bachelor's degree	0.155*** (0.123, 0.186)
Bachelor's degree or more	Reference
Unknown	0.132 (−0.059, 0.323)
Net worth	
Less than $25k	0.717*** (0.682, 0.752)
$25k–149k	0.431*** (0.397, 0.465)
$150k–249k	0.317*** (0.278, 0.356)
$250k–499k	0.223*** (0.190, 0.256)
$500k or greater	Reference
Unknown	0.523*** (0.477, 0.569)

Note:
*p<.05.
**p<.01.
*** p<.001.

with less post-operative pain and disability, as well as increased rates of ability to work and return to work by three months and one-year post-operatively [54]. While these studies suggest there are SES disparities regarding post-operative spine surgery outcomes, it has also been demonstrated that patients who live in higher ADI neighborhoods do not have worse long-term physical and mental health after lumbar spine surgery, suggesting that lower SES patients experience similar long-term health benefits as higher SES patients [55]. Thus, ensuring equitable access to spine surgical care for patients with lower SES is essential so that they can experience the same long-term benefits of spine surgery as those of higher SES.

Our study is limited by its design as a retrospective database review. We are unable to assess trends beyond correlations since the retrospective nature of these observational data may hide confounding variables. These databases are limited in terms of accuracy, especially for certain measures such as net worth [56]; completion, though all categories included in the study have reasonable quantities of unknown responses (all<10%); and how information is stratified in CDM (e.g., racial, education, and income brackets are all pre-defined by CDM). For example, net worths of $25k–150k are grouped in one bracket, though this range encompasses people of significantly varying wealth. Another important caveat is that net worth is not reported by the beneficiaries themselves (although this too would be prone to bias), but it is instead derived via linking to an external commercial vendor in a proprietary manner that is not made available to researchers. Another example is that only self-identified White, Black, Asian, and Hispanic races are included, which excludes "American Indian or Alaska Native," "Native Hawaiian or other Pacific Islander," and multiracial designations, all of which are minority groups identified by the U.S. Census [57]. As such, health disparities may be obscured within these broader groupings or by exclusion altogether. Additionally, our data is limited by the sampling biases inherent in the population of patients whose data is reported in CDM; while our trends (including geographical variation) match those previously reported in the literature, they may reflect differing patient populations among commercial vs non-commercial insurers across state boundaries. Lastly, while our overall conclusion that patients with minority racial status and lower SES made up a significantly smaller proportion of the patient population during the pandemic is in line with the general healthcare literature, this may also reflect that these patients may have been more likely to lose their jobs and job-related commercial health insurance (represented in the CDM) during the pandemic.

Conclusions

To the best of our knowledge, our study represents the most recent and comprehensive characterization of demographic and socioeconomic trends in lumbar fusion surgery, including during the first year of the COVID-19 pandemic. While there have been improvements in access to surgical care for minority and low SES patients over time, there were setbacks during the pandemic, as white and wealthier patients were significantly more likely to undergo lumbar fusions. Furthermore, while there were increasing rates of minority and the lowest net worth (<$25k) patients undergoing lumbar fusions before the pandemic, from 2004 to 2019, they are still significantly under-represented compared to the entire U.S. population. Thus, significant work is needed to improve access to spine care for all U.S. patients, especially in the aftermath of the COVID-19 pandemic. Our findings are also an important lesson to heed in future public health emergencies to ensure that access to care issues do not disproportionately impact patients of lower SES.

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Declarations of competing interests

One or more of the authors declare financial or professional relationships on ICMJE-NASSJ disclosure forms.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.xnsj.2024.100321.

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