



Contents lists available at ScienceDirect

North American Spine Society Journal (NASSJ)

journal homepage: www.elsevier.com/locate/xnsj

Clinical Studies

Disparities in anterior cervical discectomy and fusion provision and outcomes for cervical stenosis



Ankita Das, BS^{a,*}, Sima Vazquez, MS^a, Alan Stein, MD^b, Jacob D. Greisman, BA^a, Christina Ng, MD^a, Tiffany Ming, BA^a, Grigori Vaserman, BS^a, Eris Spirollari, BA^a, Alexandria F. Naftchi, BS^a, Jose F. Dominguez, MD^b, Simon J. Hanft, MD^b, John Houten, MD^c, Merritt D. Kinon, MD^b

^a School of Medicine, New York Medical College, 40 Sunshine Cottage Rd, Valhalla, NY 10595, United States

^b Department of Neurosurgery, Westchester Medical Center, 100 Woods Road, Valhalla, NY 10595, United States

^c Department of Neurosurgery, Icahn School of Medicine at Mount Sinai, 1468 Madison Ave, New York, NY 10029, United States

ARTICLE INFO

Keywords:

Cervical stenosis
Disparities
Anterior cervical discectomy and fusion
Spine
Socioeconomic
Social
Myelopathy

ABSTRACT

Background: Disparities in neurosurgical care have emerged as an area of interest when considering the impact of social determinants on access to health care. Decompression via anterior cervical discectomy and fusion (ACDF) for cervical stenosis (CS) may prevent progression towards debilitating complications that may severely compromise one's quality of life. This retrospective database analysis aims to elucidate demographic and socioeconomic trends in ACDF provision and outcomes of CS-related pathologies.

Methods: The Healthcare Cost and Utilization Project National Inpatient Sample database was queried between 2016 and 2019 using International Classification of Diseases 10th edition codes for patients undergoing ACDF as a treatment for spinal cord and nerve root compression. Baseline demographics and inpatient stay measures were analyzed.

Results: Patients of White race were significantly less likely to present with manifestations of CS such as myelopathy, plegia, and bowel-bladder dysfunction. Meanwhile, Black patients and Hispanic patients were significantly more likely to experience these impairments representative of the more severe stages of the degenerative spine disease process. White race conferred a lesser risk of complications such as tracheostomy, pneumonia, and acute kidney injury in comparison to non-white race. Insurance by Medicaid and Medicare conferred significant risks in terms of more advanced disease prior to intervention and negative inpatient. Patients in the highest quartile of median income consistently fared better than patients in the lowest quartile across almost every aspect ranging from degree of progression at initial presentation to incidence of complications to healthcare resource utilization. All outcomes for patients age > 65 were worse than patients who were younger at the time of the intervention.

Conclusions: Significant disparities exist in the trajectory of CS and the risks associated with ACDF amongst various demographic cohorts. The differences between patient populations may be reflective of a larger additive burden for certain populations, especially when considering patients' intersectionality.

FDA device/drug status: Not applicable.

Author disclosures: **AD:** Nothing to disclose. **SV:** Nothing to disclose. **AS:** Nothing to disclose. **JDG:** Nothing to disclose. **CN:** Nothing to disclose. **TM:** Nothing to disclose. **GV:** Nothing to disclose. **ES:** Nothing to disclose. **AFN:** Nothing to disclose. **JFD:** Nothing to disclose. **SJH:** Nothing to disclose. **JH:** Nothing to disclose. **MDK:** Nothing to disclose.

Abbreviations: CS, cervical stenosis; ACDF, anterior cervical discectomy and fusion; SES, socioeconomic status; HRU, healthcare resource utilization; LOS, length of stay.

* Corresponding author. School of Medicine, New York Medical College, 40 Sunshine Cottage Rd, Valhalla, NY 10595, USA. Tel.: (501) 247-6111.

E-mail address: adas3@student.nymc.edu (A. Das).

<https://doi.org/10.1016/j.xnsj.2023.100217>

Received 26 February 2023; Received in revised form 28 March 2023; Accepted 3 April 2023

Available online 14 April 2023

2666-5484/© 2023 The Authors. Published by Elsevier Ltd on behalf of North American Spine Society. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Introduction

Degenerative cervical spine disease is the most common cause of cervical stenosis (CS), the primary contributor to cervical spinal cord and nerve root disorders [1,2]. Approximately 80-90% of adults aged greater than 50 years old demonstrate evidence of degenerative disc disease on magnetic resonance imaging (MRI) [3,4]. Patients with mild disease are often asymptomatic, but those with chronic compression-induced damage to the adjacent cord (ie, myelopathy) or nerve roots (ie, radiculopathy) may experience progressive deterioration of function and sensation, loss of hand dexterity, balance issues, paresthesias, lower extremity fatigue, and neck pain [2,5].

Treatment for CS varies with disease severity. The cost-effectiveness, relative safety, and validated effectiveness of anterior cervical discectomy and fusion (ACDF) has led to widespread use in symptomatic patients [6–8]. Early intervention may be valuable, as studies have found healthcare resource utilization (HRU), in the forms of pain management and outpatient charges, to be extremely high in the years leading up to ACDF [9].

Racial and sociodemographic disparities have become increasingly salient in the discussion of equitable health care and innovation that benefits all [10,11]. Socioeconomic status (SES) disparities in health care and their impact on outcomes are well-established [12–14]. Multiple studies surveying the field of neurosurgery have repeatedly identified associations between SES, race, or insurance status and rates of complications, readmission, and even underutilization of treatments at public hospitals, complications, and readmission rates [15–18].

Using the National Inpatient Sample (NIS) database, this retrospective study explores associations between sociodemographic factors and outcomes to identify the impact of social and economic determinants on access to ACDF for CS.

Methods

Data source and patient selection

The Healthcare Cost and Utilization Project's NIS, the largest publicly accessible database of all-payer inpatient data, reports data on millions of U.S. hospitalizations per year [19]. Using the International Classification of Disease, 10th Revision (ICD10), the NIS was queried from 2016 to 2019 for patients who were diagnosed with CS (M48.02). Of those patients, we compared those who received an ACDF (ORB3, ORT3, ORG1070, ORG10A0, ORG10J0, ORG10K0, ORG13170, ORG13A0, ORG13J0, ORG13K0, ORG1470, ORG14A0, ORG14J0) and those who did not. All patient information was anonymized to minimize any sources of potential bias and to protect confidentiality.

Data characteristics and outcome measures

Baseline demographics, including age, sex, race, insurance status, and comorbidities were extracted from the dataset and explored in patients with myelopathy, plegia, and bowel-bladder dysfunction. Race was stratified as White, Hispanic, Black, and Asian/Pacific in concordance with patient characteristic categories in the NIS. Quartile (Q) median household income categories were extracted and standardized according to each patient's zip code. As per Healthcare Utilization Project, Q1 is defined as the 0th to 25th percentile; Q2 is the 26th to 50th percentile; Q3 is 51st to 75th percentile; and Q4 is 76th to 100th median income percentile. Sociodemographic status herein encompassed Payer status, median household income, and insurance coverage.

Complications assessed included tracheostomy, pneumonia (PNA), acute kidney injury (AKI), sepsis, pulmonary embolism (PE), and deep vein thrombosis (DVT). Outcomes measured were total hospital charges, length of stay (LOS), and complications. Discharge disposition and prolonged LOS (>10 days) were used to measure HRU. Frailty was derived from the 11-factor modified frailty index (mFI-11), which summates

functional status, diabetes mellitus, chronic obstructive pulmonary disease, congestive heart failure, myocardial infarction, cardiac interventions, hypertension with medication, peripheral vascular disease, impaired sensorium, transient ischemic attacks without deficit, and cerebrovascular accident with neurological impairments. The mFI-11 has been previously validated in the context of spine surgery [20]. All ICD10 codes and indices utilized for the analysis can be found in the Supplementary Materials. Furthermore, the Elixhauser Comorbidity Index (ECI) was also applied to assess for comorbidities amongst the population to account for variation in the health baselines of various subgroups. Comorbidities within the ECI were selected for evaluation when they were present in at least 3% of the population. Elevated ECI was defined as having an ECI greater than 75th percentile [21].

Statistical analysis

Statistical analysis was conducted using SPSS Statistical Software (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp). Baseline characteristics were analyzed using descriptive statistical analysis. Pearson's chi-square test was used to measure odds ratios for categorical variables. Multivariate analysis was performed to analyze predictors of complications and outcomes.

Results

Characteristics of patients with advanced disease

Of the 155,300 patients undergoing ACDF, 5,660 (3.6%) reported myelopathy and 1,605 (1%) reported plegia. 660 (0.04%) patients undergoing ACDF had bowel or bladder dysfunction. Patients greater than age 65 were more likely to present with myelopathy (OR 1.727, CI 95% 1.636–1.823, $p < .001$), plegia (OR 1.797, CI 95% 1.627–1.986 $p < .001$), and bowel bladder dysfunction (OR 1.408, CI 95% 1.201–1.65, $p < .001$). Patients with myelopathy, plegia, or bowel bladder dysfunction were more likely to be male ($p < .001$, all).

Patients of white race were less likely to experience myelopathy (OR 0.835, CI 95% 0.787–0.886, $p < .001$), plegia (OR 0.476, CI 95% 0.43–0.526 $p < .001$), or bowel-bladder dysfunction (OR 0.731, CI 95% 0.619–0.864, $p < .001$). Patients of black race were more likely to present with myelopathy (OR 1.451 [1.342–1.569], $p < .001$), plegia (OR 2.443, CI 95% 2.163–2.758, $p < .001$), and bowel bladder dysfunction (OR 1.54, CI 95% 1.239–1.915, $p < .001$). Hispanic patients were more likely to report plegia (OR 1.515, CI 95% 1.286–1.786, $p < .001$) or bowel-bladder dysfunction (OR 1.364, CI 95% 1.045–1.779, $p = .025$). Asian patients were more likely to carry a diagnosis of myelopathy (OR 1.44, CI 95% 1.191–1.74, $p < .001$).

When assessing the impact of socioeconomic factors, patients in the highest income quartile (Q4) were found to demonstrate fewer associations with myelopathy and bowel bladder; these patients were significantly less likely to experience plegia (OR 0.515, CI 95% 0.445–0.595, $p < .001$). Those in the lowest quartile of median income were more likely to experience myelopathy (OR 1.125, CI 95% 1.059–1.195, $p < .001$) or plegia (OR 1.868, CI 95% 1.687–2.068, $p < .001$). Patients insured by Medicaid were more likely to have plegia (OR 1.774, CI 95% 1.552–2.028, $p < .001$) or have bowel bladder dysfunction (OR 1.349, CI 95% 1.073–1.695, $p = .011$), and patients insured by Medicare were more likely to have myelopathy (OR 1.556, CI 95% 1.475–1.641, $p < .001$), plegia (OR 1.502, CI 95% 1.361–1.658, $p < .001$), or bowel-bladder dysfunction (OR 1.457, CI 95% 1.25–1.698, $p < .001$) (Table 1).

Comorbidities and complications

Elevated ECI was associated with Black race (OR=1.454, 95% CI 1.390–1.522, $p < .001$), Medicare Insurance (OR=2.616, 95% CI 2.537–2.697, $p < .001$), and Q1 Median income (OR=1.170, 95% CI 1.131–1.210, $p < .001$). In terms of complications, age was a positive predic-

Table 1
Markers of disease severity

All (n=155,300)	Myelopathy (n=5,660) OR	Plegia (n=1,605) OR	Bowel-bladder dysfunction (n=660) OR
Age greater than 65	1.727 (1.636–1.823)	1.797 (1.627–1.986)	1.408 (1.201–1.65)
Female gender	0.848 (0.804–0.894)	0.643 (0.581–0.71)	0.703 (0.602–0.821)
Insurance—Medicare	1.556 (1.475–1.641)	1.502 (1.361–1.658)	1.457 (1.25–1.698)
Insurance—Medicaid	0.98 (0.896–1.072)	1.774 (1.552–2.028)	1.349 (1.073–1.695)
White race	0.835 (0.787–0.886)	0.476 (0.43–0.526)	0.731 (0.619–0.864)
African American race	1.451 (1.342–1.569)	2.443 (2.163–2.758)	1.54 (1.239–1.915)
Hispanic race	0.936 (0.841–1.043)	1.515 (1.286–1.786)	1.364 (1.045–1.779)
Asian/Pacific race	1.44 (1.191–1.74)	0.861 (0.553–1.341)	1.051 (0.562–1.966)
Q1 Median income	1.125 (1.059–1.195)	1.868 (1.687–2.068)	1.166 (0.982–1.384)
Q4 Median income	0.968 (0.908–1.032)	0.515 (0.445–0.595)	1.011 (0.842–1.213)

All bolded values represent significant odds ratios to a standard of <0.05.

Table 2
Medical complications

	Trach OR	Pneumonia OR	AKI OR	Sepsis OR	PE OR	DVT OR
Age > 65	0.907 (0.608–1.353)	1.549 (1.308–1.835)	2.834 (2.576–3.119)	2.127 (1.575–2.871)	3.657 (2.483–5.388)	2.578 (1.975–3.365)
Female gender	0.51 (0.356–0.73)	0.662 (0.565–0.776)	0.614 (0.56–0.674)	0.61 (0.454–0.82)	0.625 (0.445–0.879)	0.542 (0.416–0.706)
Obesity	0.968 (0.565–1.658)	1.337 (1.082–1.652)	1.346 (1.187–1.527)	0.396 (0.209–0.75)	2.43 (1.65–3.577)	0.88 (0.581–1.334)
Smoker	1.681 (1.146–2.464)	1.838 (1.542–2.189)	0.851 (0.747–0.969)	1.412 (0.998–1.999)	0.513 (0.295–0.891)	1.123 (0.804–1.568)
White race	0.597 (0.418–0.852)	0.683 (0.578–0.809)	0.589 (0.535–0.649)	1.078 (0.768–1.514)	0.816 (0.561–1.188)	0.537 (0.412–0.699)
Medicaid	0.858 (0.492–1.498)	1.134 (0.878–1.465)	1.34 (1.135–1.583)	0.592 (0.306–1.145)	5.315 (3.312–8.528)	1.063 (0.656–1.723)
Frailty	1.82 (0.949–3.491)	8.185 (6.843–9.79)	2.889 (2.51–3.325)	5.558 (3.884–7.953)	4.253 (2.729–6.629)	2.311 (1.518–3.518)
Q1 Median income	1.884 (1.325–2.677)	1.221 (1.031–1.445)	1.071 (0.967–1.186)	1.941 (1.443–2.612)	0.744 (0.494–1.122)	1.227 (0.93–1.619)

AKI, acute kidney injury; PE, pulmonary embolism; DVT, deep vein thrombosis.
All bolded values represent significant odds ratios to a standard of <0.05.

tor of PNA (OR 1.549), AKI (OR 2.834), sepsis (OR 2.127), PE (OR 3.657), and DVT (OR 2.578). Female sex was a negative predictor of tracheostomy (OR 0.51), PNA (OR 0.662), AKI (OR 0.614), sepsis (OR 0.61), PE (OR 0.625), and DVT (OR 0.542). Frailty demonstrated a positive association with PNA (OR 8.815), AKI (OR 2.889), sepsis (OR 5.558), PE (OR 4.253), and DVT (OR 2.311). Obesity was positively associated with PNA (OR 1.337), AKI (OR 1.346), and PE (OR 2.43), Smoking positively predicted upper-airway related complications such as tracheostomy (OR 1.681) and PNA (OR 1.838). White race negatively predicted tracheostomy (OR 0.597), PNA (OR 0.683), AKI (OR 0.589), and DVT (OR 0.537). Q1 median income was a positive predictor of tracheostomy (OR 1.884), PNA (OR 1.221), and sepsis (OR 1.941), while Medicaid insurance was a positive predictor of AKI (OR 1.34) and PE (OR 5.315) (Table 2).

Healthcare resource utilization

There appeared to be significant variation amongst the demographic indicators in inpatient death, discharge dispositions, and LOS. Discharge to home represented a favorable outcome in comparison to alternative discharge patterns such as discharge to a skilled nursing facility. Age 65 was a significant positive predictor of inpatient death (OR 4.264, CI 95% 3.105–5.857, p<.001) and prolonged LOS (OR 0.355, CI 95% 0.345–0.365, p<.001), while it served as a negative predictor of uncomplicated routine discharge to home without care (OR 1.943, CI 95% 1.809–2.088, p<.001). Frailty was a negative predictor of routine discharge (OR 0.476, CI 95% 0.45–0.504, p<.001) and a positive predictor of prolonged LOS (OR 2.971, CI 95% 2.67–3.305, p<.001). Obesity (OR 0.833, CI 95% 0.8–0.868, p<.001) and smoking (OR 0.867 [0.836–0.898], p<.001) were negative predictors of routine discharge. Smoking was also a positive predictor of prolonged LOS (OR 1.184, CI 95% 1.09–1.287, p<.001).

Female sex was a negative predictor of death, (OR 0.572, CI 95% 0.427–0.767, p<.001) prolonged LOS (OR 0.62, CI 95% 0.902–

1.108, p<.001), and routine discharge (OR 0.885, CI 95% 0.862–0.909, p<.001, all). White race was a negatively associated with inpatient death (OR 0.488, CI 95% 0.364–0.655, p<.001) and prolonged LOS (OR 0.512, CI 95% 0.478–0.548, p<.001), but positively associated with routine discharge (OR 1.683, CI 95% 1.633–1.733, p<.001).

Q1 median income was a negative predictor of routine discharge (OR 0.907, CI 95% 0.879–0.935, p<.001) but a positive predictor of prolonged LOS (OR 1.4, CI 95% 1.304–1.502, p<.001). Medicaid was a positive predictor of inpatient death (OR 1.896, CI 95% 1.142–3.15, p=0.013) and prolonged LOS (OR 1.818, CI 95% 1.646–2.007, p<.001) but a negative predictor of routine discharge (OR 0.707 [0.676–0.74], p<.001).

Similar patterns were found when examining total charges (US dollars) accrued over the treatment course. Age, Medicaid status, and frailty were all positively associated with increased total hospital charges (slope=10532.865, CI 95% 9706.632–11359.097; slope=5442.243, CI 95% 4182.762–6701.724), slope=19878.557, CI 95% 17968.879–21788.235), respectively; p<.001, all). Female sex, smoking history, white race, and Q1 median income were all associated with decreased charges (slope=-4931.835, CI 95% -5658.243 to -4205.427, p<.001; slope = -1549.455, CI 95% -2514.603 to -584.306, p=.002; slope = -14115.777, CI 95% -14974.462- -13257.091, p<.001; slope = -1301.362, CI 95% -2159.208 to -443.516, p=.003, respectively) (Table 3, Supplementary Table 1).

Discussion

Lower SES status demonstrated consistent associations with more advanced degenerative spine disease, less favorable outcomes, and increased HRU in our cohort of patients with CS undergoing anterior surgery. There were also significant disparities across races in terms of disease severity and incidence of complications. The perseverance of these trends across, race, SES, and insurance status suggests concerning disparities that merit attention in the continued effort towards equitable

Table 3
Health-care resource utilization

	Inpatient death OR	Routine discharge OR	Prolonged LOS OR
Age > 65	4.264 (3.105–5.857)	0.355 (0.345–0.365)	1.943 (1.809–2.088)
Female gender	0.572 (0.427–0.767)	0.885 (0.862–0.909)	0.62 (0.58–0.663)
Obesity	0.642 (0.378–1.089)	0.833 (0.8–0.868)	1 (0.902–1.108)
Smoker	0.947 (0.634–1.417)	0.867 (0.836–0.898)	1.184 (1.09–1.287)
White race	0.488 (0.364–0.655)	1.683 (1.633–1.733)	0.512 (0.478–0.548)
Medicaid	1.896 (1.142–3.15)	0.707 (0.676–0.74)	1.818 (1.646–2.007)
Frailty	2.881 (1.88–4.416)	0.476 (0.45–0.504)	2.971 (2.67–3.305)
Q1 Median income	1.056 (0.769–1.452)	0.907 (0.879–0.935)	1.4 (1.304–1.502)

All bolded values represent significant findings to a standard of <0.05.

distribution of spine care. While the efficacy of surgical treatment for CS has been well established, the true benefit is difficult to measure when social factors affect the trajectory of pathology and access to the procedure [22,23].

We found that African American and Hispanic patients displayed evidence of more advanced disease with progressive neurologic dysfunction. With regards to CS, one study demonstrated that African American patients routinely endured longer time to diagnosis and treatment of CS compared to Caucasian patients [24]. Similar trends have been documented in these populations with regards to other neurological pathologies [23,25]. One study found greater disease severity of multiple sclerosis in African Americans, while another study on primary spinal cord tumors found that African Americans were less likely to receive surgical intervention for the same diagnosis as non-African American patients [25,26]. Alesh et al. [27] found an approximately three-fold difference in incidence of anterior cervical spinal surgeries between white women and Hispanic women.

Furthermore, our study also found increased rates of complications and mortality in patients of non-white races who underwent ACDF. While these differences may be related to the increased preoperative disease severity, Khan et al. [28] suggests similar findings in African American patients undergoing spine surgery could be attributed to increased likelihood of being treated at low-volume hospitals with fewer resources, specialists, and integrated technology. Some studies suggest such racial disparities reflect deeply ingrained societal and cultural beliefs that percolate into and manifest as differences in inter-group experiences with the health-care system [24,29].

SES also appeared to significantly impact the progression of patients' degenerative disease process, with those in the lowest income quartile often subject to the most debilitating manifestations and the most damaging medical and financial consequences. CS patients in lower SES groups may not have access to care until they have progressive symptoms. Additionally, while some surgeons may perform ACDF on mildly symptomatic patients with severe CS based on imaging, patients of lower SES may be less likely to be subject to imaging that may lead to detection or to receive early surgery that could slow, minimize, or reverse the advancement of the disease due to their limited resources or access to health care [30]. Studies utilizing the Distressed Community Index as a measure of SES found SES to be an independent predictor of postoperative complications, and that risk-stratifying patients based on SES improved postoperative outcomes and complication rates [31–33]. Analysis of 10,030 ACDF patients yielded positive associations between low SES, postoperative complications, and LOS [28]. Increased rates of complications, longer lengths of stay, and lower rates of routine discharge may incite a harmful feedback loop as the potential loss of wages from inability to work may further compromise the SES status of those already in an unstable position. Furthermore, the additional financial burden on those with strained resources has been associated with a less adherence to systemic therapies and poorer patient outcomes [34,35].

Relatedly, Medicaid insurance status was associated with increased total charges and overall healthcare costs. Medicaid's relationship to SES imparts similar obstacles such as longer time to diagnoses, increased rates of complications and neuropathies, higher surgical costs, and longer intensive care unit stays [36–38]. These obstacles may be the result of differences in referral patterns by providers based on patient race or geographic aggregation of high-quality hospitals in predominantly white neighborhoods [39]. The difficulty obtaining preoperative and postoperative care may complicate the course of treatment for ACDF [37]. Any factor that impacts access to routine health care may contribute to the higher rate of severe disease in patients within the lower SES. Lastly, one study implicates the financial repercussions as a source of implicit bias, stating that physicians who treat patients within the lower SES receive less reimbursement and face a financial disadvantage due to the higher cost of treatment [31]. This highlights the ethically complex intersection of accessible, subsidized health care and provider compensation.

Altogether, it is critical to consider how a patient's outcome may be compromised by the multiplicative effects of their identities as part of multiple at-risk groups. Patients who fall within multiple subgroups associated with worse outcomes may incur a disproportionately greater burden. As such, the synergistic effects of the sociodemographic factors that affect postoperative outcomes should be integrated into risk-based assessments. For example, African American patients and Hispanic patients were found to live in the most resource-deprived areas with predominantly low-volume pituitary surgery hospitals and to be insured by Medicaid, all factors lending themselves to worse postoperative outcomes [40]. Our findings validate the layered nature of these barriers, which may deter patients within any of these populations from actively pursuing health maintenance measures and from agreeing to interventions.

It has been established that the best operative outcomes are attained in patients with a history of a year or less – early intervention is key [2]. As such, untimely treatment of patients creates an aging population with unhampered worsening disease, potentially making them poorer surgical candidates. In general, older and frail patients were more likely to experience the more severe manifestations of the disease process and less able to tolerate the stress induced by ACDF surgeries. Therefore, the value of preventive neurosurgery becomes paramount not only for optimizing patients' outcomes but also for minimizing unnecessary health-care expenditure, as proactive care may curtail the economic burden of complicated inpatient postoperative recoveries [41]. Risk-based assessments should follow a synergistic model to provide individualized care within a biopsychosocial model.

Limitations

As is the case with most retrospective studies, it is only possible to derive correlations between the findings as opposed to definitive causal relationships. Temporality is difficult to establish, and the NIS does not

capture the arc of future follow-up interactions for patients. Furthermore, database analyses are subject to inter-hospital variation due to individual differences in coding and identification of patients. It is also difficult to account for the nuanced subtleties and biases present on an individual provider level that may contribute to the perceived phenomena. Likely, there are many pre-existing conditions and sociodemographic factors not captured in our analyses that may amalgamate to impact patients' overall health. Also, some variables may serve only as limited proxies for the metric of interest; for example, median income based on a patient's zip code may not completely reflect a patient's financial status. Nonetheless, we believe our analyses captures several factors of prime importance of which providers should be aware when considering patients as candidates for ACDf.

Conclusion

Due to the variety of environmental and sociodemographic factors that influence health, accessibility, and affordability of health care, certain subpopulations are more likely to benefit optimally from ACDf, while others may experience a significant delay in care that markedly impacts their quality of life. Certain populations face a greater risk of serious adverse outcomes such as sepsis, tracheostomy, and AKI that not only affect the trajectory of recovery but also greatly increase HRU and decrease patient quality of life and satisfaction. These disparities call for active systemic solutions that may increase the equitable distribution of neurosurgical care and promote early intervention for prevention of disease progression.

Declarations of Competing Interests

None of the authors report any relevant disclosures or conflicts of interest.

Funding

No funding was necessary for the completion of this work.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:[10.1016/j.xnsj.2023.100217](https://doi.org/10.1016/j.xnsj.2023.100217).

References

- Theodore N. Degenerative cervical spondylosis. *N Engl J Med* 2020;383:159–68. doi:[10.1056/NEJMra2003558](https://doi.org/10.1056/NEJMra2003558).
- Harris P. Cervical spine stenosis. *Paraplegia* 1977;15:125–32. doi:[10.1038/sc.1977.18](https://doi.org/10.1038/sc.1977.18).
- Brinjikji W, Luetmer PH, Comstock B, et al. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. *AJNR Am J Neuroradiol* 2015;36:811–16. doi:[10.3174/ajnr.A4173](https://doi.org/10.3174/ajnr.A4173).
- Teraguchi M, Yoshimura N, Hashizume H, et al. Prevalence and distribution of intervertebral disc degeneration over the entire spine in a population-based cohort: the Wakayama Spine Study. *Osteoarthritis Cartil.* 2014;22:104–10. doi:[10.1016/j.joca.2013.10.019](https://doi.org/10.1016/j.joca.2013.10.019).
- Symon L, Lavender P. The surgical treatment of cervical spondylotic myelopathy. *Neurology* 1967;17:117–27. doi:[10.1212/wnl.17.2.117](https://doi.org/10.1212/wnl.17.2.117).
- McCormick WE, Steinmetz MP, Benzel EC. Cervical spondylotic myelopathy: make the difficult diagnosis, then refer for surgery. *Cleve Clin J Med* 2003;70:899–904. doi:[10.3949/ccjm.70.10.899](https://doi.org/10.3949/ccjm.70.10.899).
- Overley SC, McAnany SJ, Brochin RL, Kim JS, Merrill RK, Qureshi SA. The 5-year cost-effectiveness of two-level anterior cervical discectomy and fusion or cervical disc replacement: a Markov analysis. *Spine J Off J North Am Spine Soc* 2018;18:63–71. doi:[10.1016/j.spinee.2017.06.036](https://doi.org/10.1016/j.spinee.2017.06.036).
- Kamalpathy PN, Puvanesarajah V, Sequeria S, Bell J, Hassanzadeh H. Safety profile of outpatient vs inpatient ACDf: an analysis of 33,807 outpatient ACDf. *Clin Neurol Neurosurg* 2021;207:106743. doi:[10.1016/j.clineuro.2021.106743](https://doi.org/10.1016/j.clineuro.2021.106743).
- Virk S, Phillips FM, Khan S. Patterns of healthcare resource utilization prior to anterior cervical decompression and fusion in patients with radiculopathy. *Int J Spine Surg* 2017;11:25. doi:[10.14444/4025](https://doi.org/10.14444/4025).
- Meyer PA, Penman-Aguilar A, Campbell VA, et al. Conclusion and future directions: CDC health disparities and inequalities report - United States, 2013. *MMWR Suppl* 2013;62:184–6.
- Arcaya MC, Arcaya AL, Subramanian SV. Inequalities in health: definitions, concepts, and theories. *Glob Health Action* 2015;8:27106. doi:[10.3402/gha.v8.27106](https://doi.org/10.3402/gha.v8.27106).
- Fiscella K, Franks P, Gold MR, Clancy CM. Inequality in quality: addressing socioeconomic, racial, and ethnic disparities in health care. *JAMA* 2000;283:2579–84. doi:[10.1001/jama.283.19.2579](https://doi.org/10.1001/jama.283.19.2579).
- Vyas DA, Eisenstein LG, Jones DS. Hidden in plain sight - reconsidering the use of race correction in clinical algorithms. *N Engl J Med* 2020;383:874–82. doi:[10.1056/NEJMms2004740](https://doi.org/10.1056/NEJMms2004740).
- Cardinal T, Bonney PA, Strickland BA, et al. Disparities in the surgical treatment of adult spine diseases: a systematic review. *World Neurosurg* 2021;158:290–304. doi:[10.1016/j.wneu.2021.10.121](https://doi.org/10.1016/j.wneu.2021.10.121).
- Missios S, Rahmani R, Bekelis K. Spinal cord stimulators: socioeconomic disparities in four US states. *Neuromodulation J Int Neuromodulation Soc* 2014;17:451–5 discussion 455–456. doi:[10.1111/ner.12101](https://doi.org/10.1111/ner.12101).
- Lad SP, Huang KT, Bagley JH, Hazzard MA, Babu R, Owens TR, et al. Disparities in the outcomes of lumbar spinal stenosis surgery based on insurance status. *Spine* 2013;38:1119–27. doi:[10.1097/BRS.0b013e318287f04e](https://doi.org/10.1097/BRS.0b013e318287f04e).
- Nuño M, Drazin DG, Acosta FL. Differences in treatments and outcomes for idiopathic scoliosis patients treated in the United States from 1998 to 2007: impact of socioeconomic variables and ethnicity. *Spine J Off J North Am Spine Soc* 2013;13:116–23. doi:[10.1016/j.spinee.2012.10.005](https://doi.org/10.1016/j.spinee.2012.10.005).
- Lu Y, McAnany SJ, Hecht AC, Cho SK, Qureshi SA. Utilization trends of cervical artificial disc replacement after FDA approval compared with anterior cervical fusion: adoption of new technology. *Spine* 2014;39:249–55. doi:[10.1097/BRS.0000000000000113](https://doi.org/10.1097/BRS.0000000000000113).
- HCUP National Inpatient Sample (NIS). Healthcare cost and utilization project (HCUP). 2016.
- Ali R, Schwab JM, Nerenz DR, Antoine HJ, Rubinfeld I. Use of the modified frailty index to predict 30-day morbidity and mortality from spine surgery. *J Neurosurg Spine* 2016;25:537–41. doi:[10.3171/2015.10.SPINE14582](https://doi.org/10.3171/2015.10.SPINE14582).
- Moore BJ, White S, Washington R, Coenen E, Elixhauser A. Identifying Increased risk of readmission and in-hospital mortality using hospital administrative data: the AHRQ Elixhauser comorbidity index. *Med Care* 2017;55:698–705. doi:[10.1097/MLR.0000000000000735](https://doi.org/10.1097/MLR.0000000000000735).
- Khalid SI, Eldridge C, Singh R, et al. The influence of social determinants of health on single-level anterior cervical discectomy and fusion outcomes. *J Neurosurg Spine* 2021;1–6. doi:[10.3171/2021.9.SPINE211059](https://doi.org/10.3171/2021.9.SPINE211059).
- Schoenfeld AJ, Sieg RN, Li G, Bader JO, Belmont PJ, Bono CM. Outcomes after spine surgery among racial/ethnic minorities: a meta-analysis of the literature. *Spine J Off J North Am Spine Soc* 2011;11:381–8. doi:[10.1016/j.spinee.2011.03.013](https://doi.org/10.1016/j.spinee.2011.03.013).
- Elsamady AA, Adogwa O, Fialkoff J, et al. Race as an independent predictor of temporal delay in time to diagnosis and treatment in patients with cervical stenosis: a study of 133 patients with anterior cervical discectomy and fusion. *World Neurosurg* 2016;96:107–10. doi:[10.1016/j.wneu.2016.08.070](https://doi.org/10.1016/j.wneu.2016.08.070).
- Gray-Roncal K, Fitzgerald KC, Ryerson LZ, et al. Association of disease severity and socioeconomic status in black and white americans with multiple sclerosis. *Neurology* 2021;97:e881–9. doi:[10.1212/WNL.00000000000012362](https://doi.org/10.1212/WNL.00000000000012362).
- Chiu RG, Murphy BE, Zhu A, Mehta AI. Racial and ethnic disparities in the inpatient management of primary spinal cord tumors. *World Neurosurg* 2020;140:e175–84. doi:[10.1016/j.wneu.2020.04.231](https://doi.org/10.1016/j.wneu.2020.04.231).
- Alosh H, Riley LH, Skolasky RL. Insurance status, geography, race, and ethnicity as predictors of anterior cervical spine surgery rates and in-hospital mortality: an examination of United States trends from 1992 to 2005. *Spine* 2009;34:1956–62. doi:[10.1097/BRS.0b013e3181ab930e](https://doi.org/10.1097/BRS.0b013e3181ab930e).
- Khan IS, Huang E, Maeder-York W, et al. Racial disparities in outcomes after spine surgery: a systematic review and meta-analysis. *World Neurosurg* 2022;157:e232–44. doi:[10.1016/j.wneu.2021.09.140](https://doi.org/10.1016/j.wneu.2021.09.140).
- Faigle R, Urrutia VC, Cooper LA, Gottesman RF. Individual and system contributions to race and sex disparities in thrombolysis use for stroke patients in the United States. *Stroke* 2017;48:990–7. doi:[10.1161/STROKEAHA.116.015056](https://doi.org/10.1161/STROKEAHA.116.015056).
- Sheikh Taha AM, Shue J, Lebl D, Girardi F. Considerations for prophylactic surgery in asymptomatic severe cervical stenosis: review article. *HSS J Musculoskelet J Hosp Spec Surg* 2015;11:31–5. doi:[10.1007/s11420-014-9426-4](https://doi.org/10.1007/s11420-014-9426-4).
- Michaels AD, Meneveau MO, Hawkins RB, Charles EJ, Mehaffey JH. Socioeconomic risk-adjustment with the area deprivation index predicts surgical morbidity and cost. *Surgery* 2021;170:1495–500. doi:[10.1016/j.surg.2021.02.016](https://doi.org/10.1016/j.surg.2021.02.016).
- Mehaffey JH, Hawkins RB, Charles EJ, et al. Community level socioeconomic status association with surgical outcomes and resource utilisation in a regional cohort: a prospective registry analysis. *BMJ Qual Saf* 2020;29:232–7. doi:[10.1136/bmjqs-2019-009800](https://doi.org/10.1136/bmjqs-2019-009800).
- Mehaffey JH, Hawkins RB, Charles EJ, et al. Socioeconomic “Distressed Communities Index” improves surgical risk-adjustment. *Ann Surg* 2020;271:470–4. doi:[10.1097/SLA.0000000000002997](https://doi.org/10.1097/SLA.0000000000002997).
- Mendoza J, Pangal DJ, Cardinal T, et al. Systematic review of racial, socioeconomic, and insurance status disparities in neurosurgical care for intracranial tumors. *World Neurosurg* 2021;158:38–64. doi:[10.1016/j.wneu.2021.10.126](https://doi.org/10.1016/j.wneu.2021.10.126).
- Diao K, Sun Y, Yoo SK, et al. Safety-net versus private hospital setting for brain metastasis patients treated with radiosurgery alone: disparities in follow-up care and outcomes. *Cancer* 2018;124:167–75. doi:[10.1002/cncr.30984](https://doi.org/10.1002/cncr.30984).
- Younis I, Gerges M, Schwartz TH, Ramakrishna R. Impact of Medicaid insurance on outcomes following endoscopic transphenoidal pituitary surgery. *J Neurosurg* 2020;134:801–6. doi:[10.3171/2020.1.JNS192707](https://doi.org/10.3171/2020.1.JNS192707).
- El-Sayed AM, Ziewacz JE, Davis MC, et al. Insurance status and inequalities in outcomes after neurosurgery. *World Neurosurg* 2011;76:459–66. doi:[10.1016/j.wneu.2011.03.051](https://doi.org/10.1016/j.wneu.2011.03.051).

- [38] Dominguez JF, Kalakoti P, Chen X, et al. Medicaid Payer status and other factors associated with hospital length of stay in patients undergoing primary lumbar spine surgery. *Clin Neurol Neurosurg* 2020;188:105570. doi:[10.1016/j.clineuro.2019.105570](https://doi.org/10.1016/j.clineuro.2019.105570).
- [39] Xiao D, Zheng C, Jindal M, et al. Medicaid expansion and disparity reduction in surgical cancer care at high-quality hospitals. *J Am Coll Surg* 2018;226:22–9. doi:[10.1016/j.jamcollsurg.2017.09.012](https://doi.org/10.1016/j.jamcollsurg.2017.09.012).
- [40] Goljo E, Parasher AK, Iloreta AM, Shrivastava R, Govindaraj S. Racial, ethnic, and socioeconomic disparities in pituitary surgery outcomes. *Laryngoscope* 2016;126:808–14. doi:[10.1002/lary.25771](https://doi.org/10.1002/lary.25771).
- [41] Fishbein D. The pivotal role of prevention science in this syndemic. *Prev Sci Off J Soc Prev Res* 2021;22:94–9. doi:[10.1007/s11121-020-01180-w](https://doi.org/10.1007/s11121-020-01180-w).