Published in final edited form as:

Spine (Phila Pa 1976). 2023 September 15; 48(18): 1272–1281. doi:10.1097/BRS.0000000000004769.

Association of Neighborhood Socioeconomic Deprivation with Utilization and Costs of Anterior Cervical Discectomy and Fusion

Malcolm Lizzappi, BA[1], **Rachel S. Bronheim, MD**[1], **Micheal Raad, MD**[1], **Caitlin W. Hicks, MD, MS**[2], **Richard L. Skolasky, Sc.D.**[1], **Lee H. Riley, MD**[1], **Sang H. Lee, MD, PhD**[1], **Amit Jain, MD MBA**[1]

[1]Department of Orthopaedic Surgery, The Johns Hopkins University, Baltimore, MD

[2]Division of Vascular Surgery and Endovascular Therapy, Department of Surgery, Johns Hopkins University, Baltimore, MD

Abstract

Study Design.—Retrospective analysis

Objective.—The aim of our study was to analyze the association of Area Deprivation Index (ADI) with utilization and costs of elective anterior cervical discectomy and fusion (ACDF) surgery.

Summary of Background Data: ADI, a comprehensive neighborhood-level measure of socioeconomic disadvantage, has been shown to be associated with worse perioperative outcomes in a variety of surgical settings.

Methods.—The Maryland Health Services Cost Review Commission Database was queried to identify patients who underwent primary elective ACDF between 2013 and 2020 in the state. Patients were stratified into tertiles by ADI, from least disadvantaged (ADI1) to most disadvantaged (ADI3). The primary endpoints were ACDF utilization rates per 100,000 adults and episode-of-care total costs. Univariable and multivariable regression analyses were performed.

Results.—A total of 13,362 patients (4,984 inpatient and 8,378 outpatient) underwent primary ACDF during the study period. In our study, there were 2,401 (17.97%) patients residing in ADI1 neighborhoods (least deprived), 5,974 (44.71%) in ADI2, and 4,987 (37.32%) in ADI3 (most deprived). Factors associated with increased surgical utilization were: increasing ADI, outpatient surgical setting, non-hispanic ethnicity, current tobacco use, and diagnoses of: obesity, and gastroesophageal reflux disease (GERD). Factors associated with lower surgical utilization were: non-white race, rurality, Medicare/ Medicaid insurance status, and diagnoses of cervical disc herniation or myelopathy. Factors associated with higher costs of care were: increasing ADI, older age, black/ African American race, Medicare or Medicaid insurance, former tobacco use,

Address all correspondence and reprint requests to: Rachel S. Bronheim, MD, Department of Orthopaedic Surgery, The Johns Hopkins University, 601 N. Caroline Street, 5th Floor, Baltimore, MD 21287; rsbronheim@gmail.com.

Conflicts of interest: The authors declare no conflicts of interest.

The study was deemed exempt by the institutional review board.

and diagnoses of ischemic heart disease, and cervical myelopathy. Factors associated with lower costs of care were: outpatient surgical setting, female sex, and diagnoses of GERD and cervical disc herniation.

Conclusion.—Neighborhood socioeconomic deprivation is associated with increased episode-of-care costs in patients undergoing ACDF surgery. Interestingly, we found greater utilization of ACDF surgery among patients with higher ADI.

Level of Evidence: 3

Keywords

Area deprivation index; Anterior Cervical Discectomy and Fusion; Utilization; costs

INTRODUCTION

Anterior Cervical Discectomy and Fusion (ACDF) is a commonly performed surgical treatment for a variety of cervical spinal degenerative pathologies, and is highly effective at improving pain, disability, and quality of life.[1–7] Prior literature demonstrates the presence of demographic and socioeconomic disparities in spinal surgery.[8–14]Economically and socially disadvantaged groups have been previously shown to experience a variety of poor outcomes following ACDF, such as increased length of stay, postoperative ED visits, postoperative readmission, non-routine discharge, and mortality.[3,15–17] Furthermore, neighborhood disadvantage has been shown to be an independent predictor of poor healthcare outcomes, regardless of patients' individual socioeconomic status.[18]

A recently developed and validated neighborhood-based metric which incorporates several social, economic, and demographic variables is the area deprivation index (ADI).[19] ADI was developed as measure of neighborhood disadvantage and incorporates 17 measures of deprivation, including measures of poverty, housing, employment, and education level (Table 1).[20] It has proven to be a robust metric to predict poor outcomes in a variety of settings including cardiac surgery, limb amputations, management of chronic lower back pain, and cancer treatment.[21–24]

The aim of this study was to analyze the association of ADI with utilization and costs of ACDF surgery. We hypothesized that patients with higher ADI (i.e. more deprivation) would have lower utilization of ACDF surgery and higher episode-of-care costs.

METHODS

Study Design and Data Source

This is a retrospective analysis of data collected prospectively by the Maryland Health Service Cost Review Commission (HSCRC). HSCRC is a prospectively maintained database of all inpatient and outpatient hospital visits to 53 non-federal hospitals in Maryland that contains patient-level demographic, clinical, and billing data.

Data Collection

Patients undergoing primary elective ACDF in either the inpatient or outpatient setting between 2013 and 2020 were identified in HSCRC using the International Classification of Disease (ICD) procedure codes. All patients included in this study were adults. Demographic information collected included age, sex, race/ethnicity, ADI percentile, geographic status, insurance status, and smoking status. Preoperative medical comorbidities collected included obesity, diabetes, hypertension, hyperlipidemia, ischemic heart disease, gastroesophageal reflux disease (GERD), and rheumatoid arthritis. Information was also collected on indication for surgery. Diagnoses, co-morbidities, and eligible procedures were identified using CPT, ICD-9, and ICD-10 codes. Patients who had non-elective indications (infection, trauma, revision, and malignancy) or additional procedures (multilevel, posterior approaches, non-cervical fusions) were excluded from analysis. Patients without a zip code in their record were also excluded from analysis. Patients with multiple insurance providers were categorized as private if they had any private coverage.

Area Deprivation Index

Area Deprivation Index (ADI) data for the state of Maryland was obtained from University of Wisconsin-Madison School of Medicine's Neighborhood Atlas.[19]ADI percentile scores increase with increasing neighborhood disadvantage. State level ADI decile scores are available for 9-digit Zip Code Tabulation Areas (ZCTA). For the purposes of this study, ADI deciles for the state of Maryland were averaged for 5-digit ZCTA. The Missouri Census Data Center's Census geographic crosswalk was utilized to match ZCTA to ADI percentiles, and to determine geographic rurality, as described in prior literature.[22,25] Neighborhoods were then categorized into 3 tertiles of ADI based on categorically defined cut offs, consistent with the methodology of previous studies.[22] Population data was obtained from the US Census.[26]

Endpoints of Interest

Primary endpoints were ACDF utilization rates and inflation adjusted total-episode-of-care-charges in 2020 dollars. The State of Maryland has a unique all-payer model in which hospital reimbursement for services is set by a central body, HSCRC, and is the same across all payers. Thus, the episode-of-care charges reported in the database are approximately the same as the costs to payers (insurers). There are minor adjustments that are made at year end to account for care for the uninsured and other quality metrics that hospitals receive. Utilization rate was defined as procedures per capita per 100,000 adults within a 5-digit zip code.

Statistical Analysis

Baseline patient characteristics were described using percentages for categorical variables and mean with standard deviation for continuous variables. Utilization rate was reported as a rate per 100,000 adults and compared among ADI groups using ANOVA testing. Perioperative costs were reported in inflation adjusted US dollars, standardized to 2020 dollars, and compared among ADI groups using ANOVA testing.

Univariable analysis was performed to identify risk factors associated with costs and utilization rates. Variables with a P value of 0.25 or less were included in a multivariable logistic regression. Statistical significance was set at an alpha of 0.05 for the multivariable models. Statistical analysis was performed with Stata/MP version 17 (StataCorp, College Station, TX).

RESULTS

Study Population

Overall, 13,362 patients (4,984 inpatient and 8,378 outpatient) underwent primary ACDF during the study period. In our study, there were 2,401 (17.97%) patients residing in ADI1 neighborhoods (least deprived), 5,974 (44.71%) in ADI2, and 4,987 (37.32%) in ADI3 (most deprived) [Figure 1]. Our study population demonstrated similar demographics to other studies of the ACDF population (Table 2).

ACDF Utilization

The mean annual primary elective ACDF utilization rate across all ZIP codes in Maryland was 51.6 ± 28.7 per 100,000 adults. ACDF utilization rates increased with greater neighborhood deprivation; ADI1, the least deprived tertile, utilized the least ACDF procedures per capita, while the ADI3 group had the highest utilization rate. The mean primary elective ACDF rates per 100,000 adults in a Maryland Zip Census Tabulation Area (ZCTA) were 41.06 ± 27.67 in the ADI1 group, 51.06 ± 30.58 in ADI2, and 57.3 ± 25.23 in the ADI3 group (Table 3, $p < 0.001$ for all) [Figure 2].

Multivariable analysis revealed the following factors to be associated with increased ACDF utilization: increasing ADI, outpatient surgical setting, non-hispanic ethnicity, current tobacco use, and diagnoses of obesity and GERD. The following factors were associated with decreased ACDF utilization: non-white race, rurality, Medicare or Medicaid insurance, and diagnoses of cervical disc herniation or myelopathy (Table 4).

Perioperative Costs

After adjusting for inflation, the mean episode-of-care perioperative costs for ACDFs from 2013 to 2020 in our population was $22,495 ± $12,640 in 2020 dollars. Costs increased with greater neighborhood deprivation; ADI1, the least deprived group, had the lowest perioperative costs, while ADI3 (the most deprived group) had the highest; $21, 496 ± 10,468 in ADI1 group, $22,481 ± 10,934 in ADI2, and $22,994 ± 15,213 in ADI3 (Table 4, $p<0.05$ vs. ADI1) [Figure 3].

Based on multivariable analysis, the following factors were associated with increased perioperative costs: increasing ADI, older age, black/ African American race, Medicare or Medicaid insurance, former tobacco use, and diagnoses of ischemic heart disease or cervical myelopathy. The following factors were associated with decreased perioperative costs: outpatient surgical setting, female sex, and diagnoses of GERD and cervical disc herniation (Table 5).

DISCUSSION

Previous studies have shown that patient-level demographic and socioeconomic factors are associated with disparate outcomes following spinal surgery.[3,8–12,15–17,27–29] In the current study, we demonstrate that neighborhood socioeconomic deprivation is associated with increased perioperative costs and utilization of ACDF. Additionally, our study found greater rates of obesity, hypertension, diabetes mellitus, GERD, and myelopathy with increasing ADI tertile, which is in accordance with health economics literature that shows more deprived populations to have higher rates of chronic comorbid conditions.[30]

Our analysis revealed an annual utilization rate of 51.6 per 100,000 adults in the state of Maryland. This rate is commensurate to those reported in orthopedic literature.[31–33] Interestingly, we found that worsening neighborhood disadvantage is associated with higher rates of utilization of ACDF. This finding was unexpected, as we hypothesized that patients who resided in deprived neighborhoods would have lower access to elective surgery, as has been previously demonstrated by Zhang et al. for diabetic patients seeking minor amputations.[34]

There may be several reasons for our finding. First, it is possible that patients living in higher ADI neighborhoods (i.e. more deprivation) may have more severe disease at presentation, and therefore require surgical intervention at an increased rate. Bernstein et al. previously demonstrated that greater socioeconomic disadvantage was associated with worse symptoms at initial presentation in patients seeking care for lumbar disc herniations.[35] It is possible that patients who live in more geographically deprived areas are predisposed to cervical spine pathology because of inflammatory environmental exposures, higher rates of manual labor in their occupations, deferral of care due to poor interactions with the health care system, cumulative effect of poor ergonomics at home, and many other possible effects of living alongside greater rates of the 17 measures in the area deprivation index. Alternatively, area deprivation could be coincident with psychopathology leading to complex pain syndromes, resulting in greater operative management. While clinical and radiographic data is not available in the HSCRC database, it is possible that patients living in more deprived neighborhoods had worse clinical burden of disease in our population, which may translate to higher surgical utilization rates. It is possible that systemic increase in access to earlier nonoperative care for geographically deprived people would result in parity of surgical utilization. Second, Maryland has a unique healthcare model where hospitals receive similar payments for services from all insurers due to an all-payer system. We hypothesize that patients in Maryland with higher socioeconomic burden may be at less disadvantage compared to patients in other states in terms of accessing surgical care. A recent systematic review by Shammas et al. demonstrated that the Maryland model is associated with improved outcomes and lower costs since implementation of the global budget revenue model in 2013.[36] In contrast to inpatient hospital care, physician payments and outpatient services are not covered under the Maryland model; thus, disparities may still exist in accessing outpatient care, such as non-operative treatments like epidural injections or physical therapy for cervical degenerative conditions. Interestingly, most of the patients who underwent ACDF in this cohort live in urban settings rather than rural settings. This reflects the need for geographic analysis beyond ADI for sufficient surveillance of surgical indications and overall access to surgical care in rural settings.

An additional important finding of our study is that increasing neighborhood deprivation was associated with greater perioperative costs. This was true both in the inpatient setting as well as the outpatient setting. This is consistent with a maturing body of literature that demonstrates greater charges or costs associated with spine surgery in patients of economic, social, or geographic disadvantage. In a study of charges associated with outpatient ACDF, patient race, median household income quartile for patient's ZIP code, rurality, chronic conditions, Charlson comorbidity index, number of levels fused, and number of diagnoses were all significant predictors of increased cost.[37] In a multistate analysis of lumbar spinal fusion surgery between 2007 and 2014, patients of black race were found to have higher total hospital charges compared to those of white or Caucasian race.[11] Furthermore, patients with opioid dependence were found to have significantly greater charges than those without.[38] This trend persists among those with chronic medical comorbidities as well. In a retrospective analysis of patients who underwent ACDF, patients with both severe obesity and diabetes mellitus had significantly greater charges than those with only one of those comorbidities.[39] Lumbar degenerative surgery in patients with obesity was associated with higher costs for payors over two years postoperatively.[40]

The strengths and limitations of this study stem from the data source, the HSCRC. The HSCRC is a comprehensive and longitudinal database that contains information on all inpatient and outpatient hospital visits within Maryland. First, the database lacks any clinical or radiographic data. Second, the database lacks information on out of state utilization of services by Marylanders, which could be significant, given that Maryland is bordered by regions with rich health care infrastructure. For example, there is lower utilization from ADI1 (least disadvantaged) zip codes northeast of Washington, D.C. It is possible these patients may have been seeking care in D.C. or Virginia, but were not included in our analysis.

An additional potential limitation to this study is the manner in which ADI is calculated. National ADI percentiles are tabulated for each 9-digit Zip Code Tabulation Area (ZCTA). For state level ADI data, for each 9-digit Zip Code Tabulation Area (ZCTA) is assigned a decile. According to the Neighborhood Atlas team at University of Wisconsin who provides the ADI data, "ADI should not be used at any levels other than those core geographic units defined by the Census." However to assign geographic deprivation value to each neighborhood within this study cohort, it was necessary to condense ADI deciles to match the database's geographic unit of 5-digit zip code, as previously described.[41] We also summarize ADI into broader groups of ADI tertiles as previously described.[22] There are open questions about the validity of averaging deciles without population level weighting, as this may particularly impact zip codes with a greater variability in geographic deprivation. Though our approach may decrease granularity, the simultaneous generalization of ADI data to 5-digit zip code and ADI decile scale to tertile works in the spirit of the remarks of the UW Neighborhood Atlas team's regarding use of ADI at non-census level tracts. This approach is friendlier to medical epidemiology where inclusion of 9-digit zip conflicts with the need to protect patient identity. Previous studies have performed sensitivity analysis with in-house data to lend credence to the 5-digit-zip-adi-group approach, but our sensitivity analysis lacked enough observations for statistical power. However, calculating ADI before anonymization may offer the opportunity to abandon ADI tertile approaches.[42]

While ADI captures 17 measures of neighborhood deprivation including education, income, housing, and household characteristics, it fails to capture several important environmental and community level health factors. Despite its robustness, ADI cannot account for other potential macro determinants of health including community-level comorbidity burdens or ecological factors. Additionally, ADI cannot account for dynamic processes, such as gentrification, which might elevate the overall ADI percentile while contributing to ongoing alienation and adverse health outcomes of those being actively displaced. Furthermore, rurality was an independent predictor of utilization, suggesting that use of ADI tertiles may be too general or ADI itself may not capture all aspects of geographic determination. If ADI continues to prove a valuable tool in epidemiological study of orthopedic procedures, comparison of ADI with other geographic disparity measurements will be useful.

Greater utilization of costly decompressive cervical surgery for geographically deprived individuals in the state of Maryland presents an opportunity to further reduce cost. Health policy advisors might push for inclusion of ADI national percentile and state decile before deanonymization to guide research towards cost savings. Experimenting with offering earlier non-operative treatment could be measured with greater granularity with this data, and could result in both decreased utilization and decreased perioperative charges for the most geographically deprived.

One of our study's weaknesses is the specificity of our data. Further study could attempt to reconstitute ADI into its 17 elements to aid in detection of root causes of geographic disparity. Additional study of orthopedic procedures and ADI could reveal discordant patterns, illuminating a field of differential factors contributing to charges and utilization for all patients. If geographic deprivation does indeed contribute to patients' need for surgery, it may also contribute to poor outcomes, such as pseudoarthrosis, infection, or instrumentation failure. Future studies could further situate equity in cost and utilization with severity of indication.

CONCLUSION

This study demonstrates that neighborhood deprivation, as measured by ADI, is associated with higher perioperative costs and higher utilization of ACDF in a population of patients receiving surgical care in the state of Maryland. Further study of the drivers of utilization in deprived populations, as well as interventions to reduce perioperative costs may be warranted to improve healthcare equity.

Funding:

This study was supported in part by the National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS) of the National Institutes of Health under award number T32 AR07708-08 (RSB).

REFERENCES

1. Klein GR, Vaccaro AR, Albert TJ. Health outcome assessment before and after anterior cervical discectomy and fusion for radiculopathy: a prospective analysis. Spine (Phila Pa 1976). Apr 1 2000;25(7):801–3. doi:10.1097/00007632-200004010-00007 [PubMed: 10751290]
2. Bohlman HH, Emery SE, Goodfellow DB, Jones PK. Robinson anterior cervical discectomy and arthrodesis for cervical radiculopathy. Long-term follow-up of one hundred and twenty-two patients. J Bone Joint Surg Am. Sep 1993;75(9):1298–307. doi:10.2106/00004623-199309000-00005 [PubMed: 8408151]
3. Rasouli JJ, Neifert SN, Gal JS, et al. Disparities in Outcomes by Insurance Payer Groups for Patients Undergoing Anterior Cervical Discectomy and Fusion. Spine (Phila Pa 1976). Jun 1 2020;45(11):770–775. doi:10.1097/brs.0000000000003365 [PubMed: 31842107]
4. Patil PG, Turner DA, Pietrobon R. National trends in surgical procedures for degenerative cervical spine disease: 1990–2000. Neurosurgery. Oct 2005;57(4):753–8; discussion 753–8. [PubMed: 16239888]
5. Marawar S, Girardi FP, Sama AA, et al. National trends in anterior cervical fusion procedures. Spine (Phila Pa 1976). Jul 1 2010;35(15):1454–9. doi:10.1097/BRS.0b013e3181bef3cb [PubMed: 20216341]
6. Fowler SB, Anthony-Phillips P, Mehta D, Liebman K. Health-related quality of life in patients undergoing anterior cervical discectomy fusion. J Neurosci Nurs. Apr 2005;37(2):97–100. [PubMed: 15902952]
7. Yue WM, Brodner W, Highland TR. Long-term results after anterior cervical discectomy and fusion with allograft and plating: a 5- to 11-year radiologic and clinical follow-up study. Spine (Phila Pa 1976). Oct 1 2005;30(19):2138–44. doi:10.1097/01.brs.0000180479.63092.17 [PubMed: 16205338]
8. Ghosh AK, Geisler BP, Ibrahim S. Racial/ethnic and socioeconomic variations in hospital length of stay: A state-based analysis. Medicine (Baltimore). May 21 2021;100(20):e25976. doi:10.1097/md.0000000000025976 [PubMed: 34011086]
9. Lieber AM, Boniello AJ, Kerbel YE, et al. Low Socioeconomic Status Is Associated With Increased Complication Rates: Are Risk Adjustment Models Necessary in Cervical Spine Surgery? Global Spine J. Sep 2020;10(6):748–753. doi:10.1177/2192568219874763 [PubMed: 32707010]
10. Dial BL, Esposito VR, Danilkowicz R, et al. Factors Associated With Extended Length of Stay and 90-Day Readmission Rates Following ACDF. Global Spine J May 2020;10(3):252–260. doi:10.1177/2192568219843111 [PubMed: 32313789]
11. Aladdin DEH, Tangel V, Lui B, Pryor KO, Witkin LR, White RS. Black Race as a Social Determinant of Health and Outcomes After Lumbar Spinal Fusion Surgery: A Multistate Analysis, 2007 to 2014. Spine (Phila Pa 1976). May 15 2020;45(10):701–711. doi:10.1097/brs.0000000000003367 [PubMed: 31939767]
12. Di Capua J, Somani S, Kim JS, et al. Predictors for Patient Discharge Destination After Elective Anterior Cervical Discectomy and Fusion. Spine (Phila Pa 1976). Oct 15 2017;42(20):1538–1544. doi:10.1097/brs.0000000000002140 [PubMed: 28252556]
13. Skolasky RL, Thorpe RJ Jr., Wegener ST, Riley LH 3rd. Complications and mortality in cervical spine surgery: racial differences. Spine (Phila Pa 1976). Aug 15 2014;39(18):1506–12. doi:10.1097/brs.0000000000000429 [PubMed: 24859586]
14. Alosh H, Riley LH 3rd, 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 (Phila Pa 1976). Aug 15 2009;34(18):1956–62. doi:10.1097/BRS.0b013e3181ab930e [PubMed: 19652634]
15. Rumalla K, Smith KA, Arnold PM. Cervical Total Disc Replacement and Anterior Cervical Discectomy and Fusion: Reoperation Rates, Complications, and Hospital Resource Utilization in 72 688 Patients in the United States. Neurosurgery. Apr 1 2018;82(4):441–453. doi:10.1093/neuros/nyx289 [PubMed: 28973385]
16. Feng R, Finkelstein M, Bilal K, Oermann EK, Palese M, Caridi J. Trends and Disparities in Cervical Spine Fusion Procedures Utilization in the New York State. Spine (Phila Pa 1976). May 15 2018;43(10):E601–e606. doi:10.1097/brs.0000000000002438 [PubMed: 29016436]

17. Sanford Z, Taylor H, Fiorentino A, et al. Racial Disparities in Surgical Outcomes After Spine Surgery: An ACS-NSQIP Analysis. Global Spine J Sep 2019;9(6):583–590. doi:10.1177/2192568218811633 [PubMed: 31448190]
18. Ludwig J, Sanbonmatsu L, Gennetian L, et al. Neighborhoods, obesity, and diabetes--a randomized social experiment. N Engl J Med. Oct 20 2011;365(16):1509–19. doi:10.1056/NEJMsa1103216 [PubMed: 22010917]
19. Kind AJH, Buckingham WR. Making Neighborhood-Disadvantage Metrics Accessible - The Neighborhood Atlas. N Engl J Med. Jun 28 2018;378(26):2456–2458. doi:10.1056/NEJMp1802313 [PubMed: 29949490]
20. Han JJ, Iyengar A, Fowler C, et al. Impact of Socioeconomic Status on Outcomes After Ventricular Assist Device Implantation Using the Area Deprivation Index. J Card Fail. May 2021;27(5):597–601. doi:10.1016/j.cardfail.2021.01.010 [PubMed: 33962744]
21. Hu J, Kind AJH, Nerenz D. Area Deprivation Index Predicts Readmission Risk at an Urban Teaching Hospital. Am J Med Qual. Sep/Oct 2018;33(5):493–501. doi:10.1177/1062860617753063 [PubMed: 29357679]
22. Zhang GQ, Canner JK, Kayssi A, Abularrage CJ, Hicks CW. Geographical socioeconomic disadvantage is associated with adverse outcomes following major amputation in diabetic patients. J Vasc Surg. Oct 2021;74(4):1317–1326.e1. doi:10.1016/j.jvs.2021.03.033 [PubMed: 33865949]
23. Rosenzweig MQ, Althouse AD, Sabik L, et al. The Association Between Area Deprivation Index and Patient-Reported Outcomes in Patients with Advanced Cancer. Health Equity. 2021;5(1):8–16. doi:10.1089/heq.2020.0037 [PubMed: 33564735]
24. Rassu FS, McFadden M, Aaron RV, et al. The Relationship Between Neighborhood Deprivation and Perceived Changes for Pain-Related Experiences Among US Patients with Chronic Low Back Pain During the COVID-19 Pandemic. Pain Med. Nov 26 2021;22(11):2550–2565. doi:10.1093/pm/pnab179 [PubMed: 34181008]
25. Commission MHSCR. HSCRC Overview. State of Maryland. Accessed June 1, 2020. https://hscrc.maryland.gov/pages/default.aspx
26. Bureau USC. 2020 Census Results. 2021. https://www.census.gov/programs-surveys/decennial-census/decade/2020/2020-census-results.html
27. Elsamadicy AA, Koo AB, David WB, et al. Portending Influence of Racial Disparities on Extended Length of Stay after Elective Anterior Cervical Discectomy and Interbody Fusion for Cervical Spondylotic Myelopathy. World Neurosurg. Oct 2020;142:e173–e182. doi:10.1016/j.wneu.2020.06.155 [PubMed: 32599203]
28. Tighe P, Modave F, Horodyski M, et al. Geospatial Analyses of Pain Intensity and Opioid Unit Doses Prescribed on the Day of Discharge Following Orthopedic Surgery. Pain Med. Aug 1 2020;21(8):1644–1662. doi:10.1093/pm/pnz311 [PubMed: 31800063]
29. Ye Y, Beachy MW, Luo J, et al. Geospatial, Clinical, and Social Determinants of Hospital Readmissions. Am J Med Qual. Nov/Dec 2019;34(6):607–614. doi:10.1177/1062860619833306 [PubMed: 30834776]
30. Kind AJ, Jencks S, Brock J, et al. Neighborhood socioeconomic disadvantage and 30-day rehospitalization: a retrospective cohort study. Ann Intern Med. Dec 2 2014;161(11):765–74. doi:10.7326/m13-2946 [PubMed: 25437404]
31. Saifi C, Fein AW, Cazzulino A, et al. Trends in resource utilization and rate of cervical disc arthroplasty and anterior cervical discectomy and fusion throughout the United States from 2006 to 2013. Spine J. Jun 2018;18(6):1022–1029. doi:10.1016/j.spinee.2017.10.072 [PubMed: 29128581]
32. Lopez CD, Boddapati V, Lombardi JM, et al. Recent trends in medicare utilization and reimbursement for anterior cervical discectomy and fusion. Spine J. Nov 2020;20(11):1737–1743. doi:10.1016/j.spinee.2020.06.010 [PubMed: 32562771]
33. Neifert SN, Martini ML, Yuk F, et al. Predicting Trends in Cervical Spinal Surgery in the United States from 2020 to 2040. World Neurosurg. Sep 2020;141:e175–e181. doi:10.1016/j.wneu.2020.05.055 [PubMed: 32416237]

34. Zhang GQ, Canner JK, Haut E, Sherman RL, Abularrage CJ, Hicks CW. Impact of Geographic Socioeconomic Disadvantage on Minor Amputation Outcomes in Patients With Diabetes. J Surg Res. Feb 2021;258:38–46. doi:10.1016/j.jss.2020.08.039 [PubMed: 32980774]

35. Bernstein DN, Merchan N, Fear K, Rubery PT, Mesfin A. Greater Socioeconomic Disadvantage Is Associated with Worse Symptom Severity at Initial Presentation in Patients Seeking Care for Lumbar Disc Herniation. Spine (Phila Pa 1976). Apr 1 2021;46(7):464–471. doi:10.1097/brs.0000000000003811 [PubMed: 33181773]

36. Shammas RL, Coroneos CJ, Ortiz-Babilonia C, Graton M, Jain A, Offodile AC, 2nd. Implementation of the Maryland Global Budget Revenue Model and Variation in the Expenditures and Outcomes of Surgical Care: A Systematic Review and Meta-Analysis. Ann Surg. Oct 31 2022;doi:10.1097/sla.0000000000005744

37. Purger DA, Pendharkar AV, Ho AL, et al. Outpatient vs Inpatient Anterior Cervical Discectomy and Fusion: A Population-Level Analysis of Outcomes and Cost. Neurosurgery. Apr 1 2018;82(4):454–464. doi:10.1093/neuros/nyx215 [PubMed: 28498922]

38. Berg J, Wahood W, Zreik J, et al. Economic Burden of Hospitalizations Associated with Opioid Dependence Among Patients Undergoing Spinal Fusion. World Neurosurg. Jul 2021;151:e738–e746. doi:10.1016/j.wneu.2021.04.116 [PubMed: 34243673]

39. Walid MS, Robinson JS Jr. Economic impact of comorbidities in spine surgery. J Neurosurg Spine. Mar 2011;14(3):318–21. doi:10.3171/2010.11.spine10139 [PubMed: 21235301]

40. Varshneya K, Wadhwa H, Stienen MN, et al. Obesity in Patients Undergoing Lumbar Degenerative Surgery-A Retrospective Cohort Study of Postoperative Outcomes. Spine (Phila Pa 1976). Sep 1 2021;46(17):1191–1196. doi:10.1097/brs.0000000000004001 [PubMed: 34384097]

41. Rahman R, Canner JK, Haut ER, Humbyrd CJ. Is Geographic Socioeconomic Disadvantage Associated with the Rate of THA in Medicare-aged Patients? Clin Orthop Relat Res. Mar 1 2021;479(3):575–585. doi:10.1097/corr.0000000000001493 [PubMed: 32947286]

42. Nkoy FL, Stone BL, Knighton AJ, et al. Neighborhood Deprivation and Childhood Asthma Outcomes, Accounting for Insurance Coverage. Hosp Pediatr. Jan 9 2018;doi:10.1542/hpeds.2017-0032

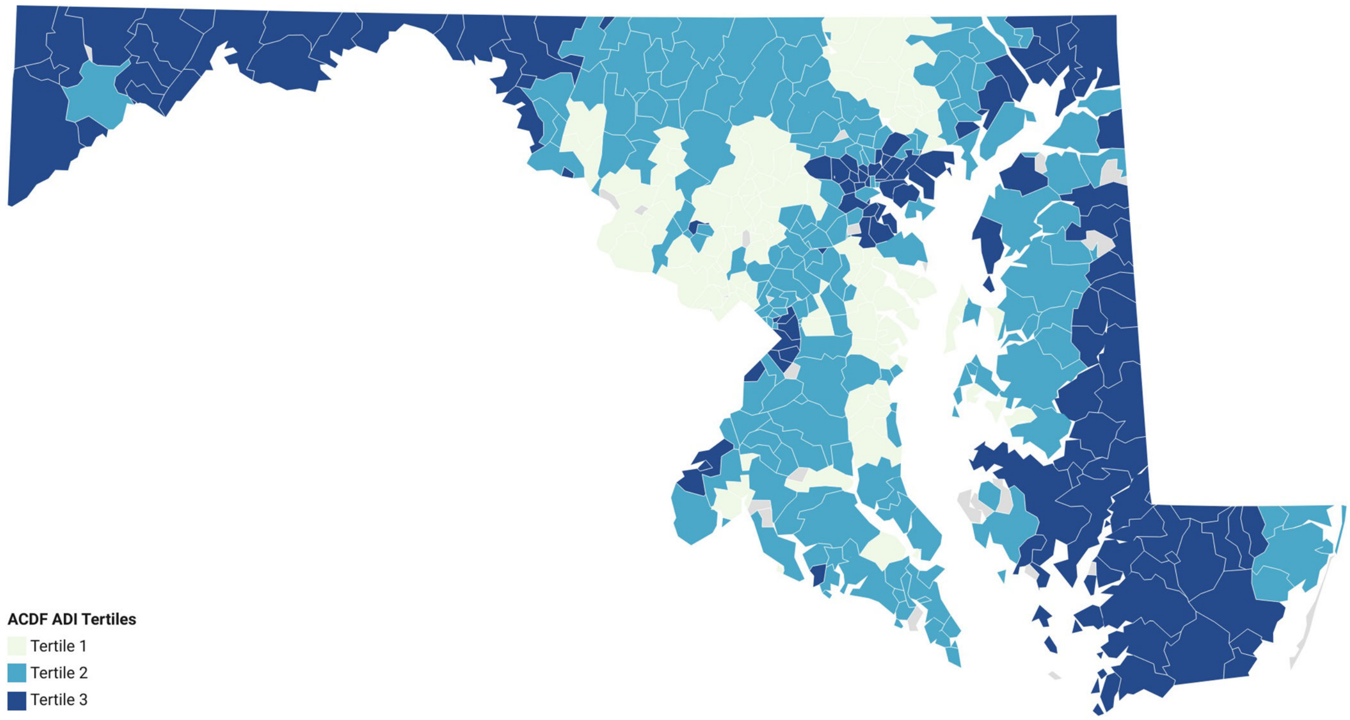

Figure 1-
Geographic Distribution of Area Deprivation Index, By Tertile

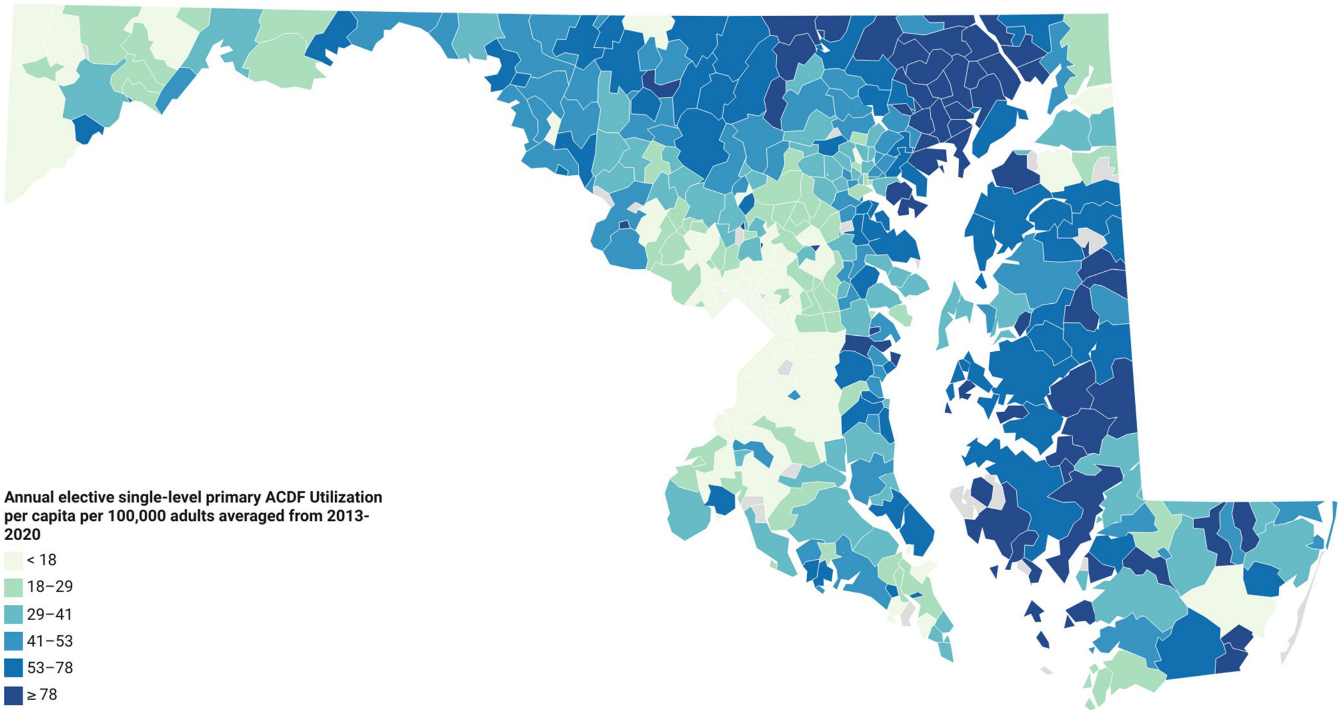

Figure 2-

Geographic Distribution of Elective Single-Level ACDF Utilization Per Capita Per 100,000 Adults, Averaged From 2013–2020

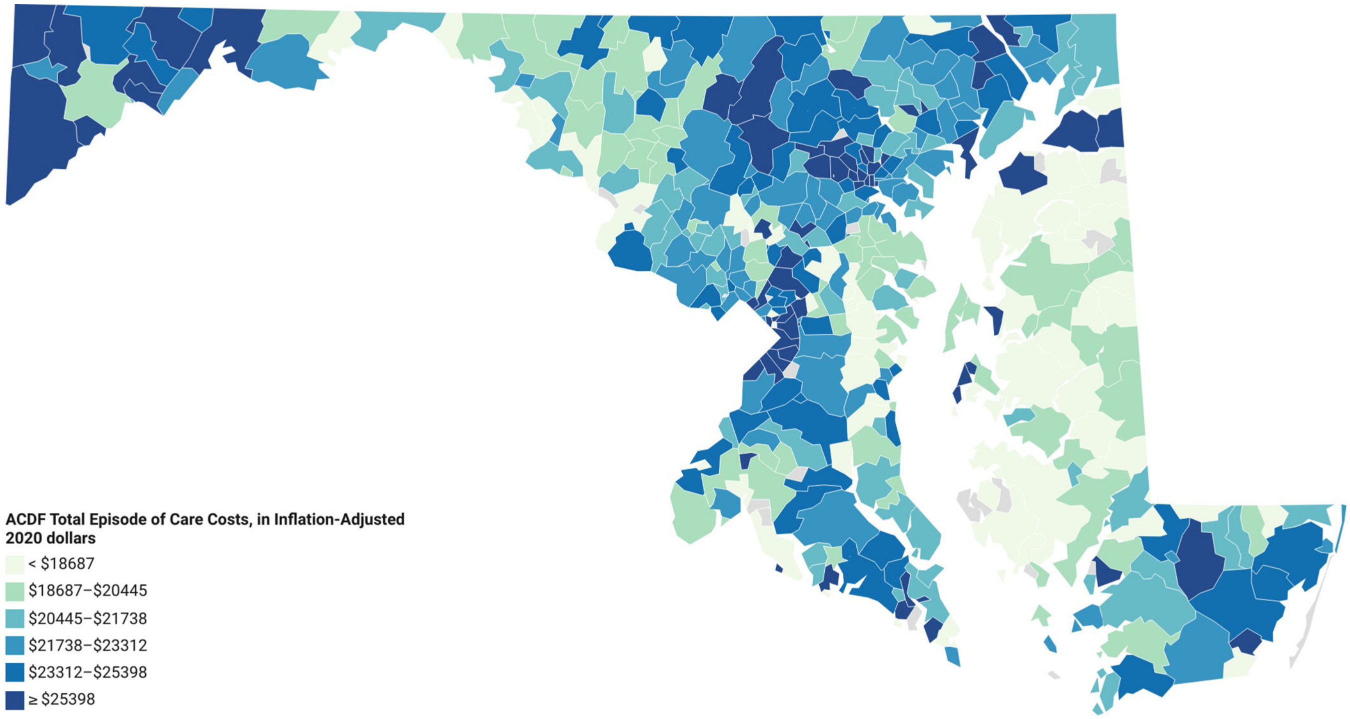

Figure 3-

Geographic Distribution of ACDF Total Episode of Care Costs, in Inflation-Adjusted 2020 Dollars

Table 1:

Components of Area Deprivation Index

Domain	*Variable*
Education	1. % Population aged 25 years or older with less than 9 years of education 2. % Population aged 25 years or older with at least a high school diploma 3. % Employed population aged 16 years or older in white-collar occupations
Income/employment	4. Median family income in US dollars 5. Income disparity 6. % Families below federal poverty level 7. % Population below 150% of federal poverty level 8. % Civilian labor force population aged 16 years and older who are unemployed
Housing	9. Median home value in US dollars 10. Median gross rent in US dollars 11. Median monthly mortgage in US dollars 12. % Owner-occupied housing units 13. % Occupied housing units without complete plumbing
Household characteristics	14. % Single-parent households with children younger than 18 15. % Households without a motor vehicle 16. % Households without a telephone 17. % Households with more than 1 person per room

Table 2.

Demographic and clinical characteristics of patients receiving anterior cervical discectomy and fusion (ACDF) in Maryland (2013–2020), stratified by Maryland specific area deprivation index (ADI) tertile

ADI percentile	ADI 1	ADI 2	ADI 3
Total	2,401 (17.97)	5,974 (44.71)	4,987 (37.32)
Setting			
Inpatient	863 (35.94)	2,165 (36.24)	1,956 (39.22)
Outpatient	1,538 (64.06)	3,809 (63.76)	3,031 (60.78)
Age (years)			
18–39	152 (6.33)	509 (8.52)	491(9.85)
40–64	1,481 (61.68)	3,703 (61.99)	3,206 (64.29)
>65	768 (31.99)	1,762 (29.49)	1,290 (25.87)
Sex			
Male	1,182 (49.23)	2,762 (46.23)	2,137 (42.85)
Female	1,219 (50.77)	3,212 (53.77)	2,850 (57.15)
Race			
White	1,545 (64.35)	3,606 (60.36)	2,532 (50.77)
Black/African American	644 (26.82)	1,795 (30.05)	2,015 (40.41)
Asian	42 (1.75)	76 (1.27)	27 (0.54)
American Indian/ Alaska Native	7 (0.29)	13 (0.22)	10 (0.20)
Hawaiian/ Pacific Islander	40 (1.67)	109 (1.82)	60 (1.20)
Multi-Racial	4 (0.17)	10 (0.17)	13 (0.26)
Other	119 (4.96)	365 (6.11)	330 (6.62)
Ethnicity			
Hispanic	46 (1.92)	138 (2.31)	73 (1.46)
Non-Hispanic	2,242 (93.38)	5,518 (92.37)	4,696 (94.16)
Declined/Unknown	113 (4.71)	318 (5.32)	218 (4.37)
Geographic Status			
Rural	152 (6.33)	283 (4.74)	315 (6.32)
Urban	2,249 (93.67)	5,691 (95.26)	4,672 (93.68)
Insurance			
Private	2,274 (94.71)	5,520 (92.40)	4,387 (89.21)
Medicare	79 (3.29)	256 (4.39)	350 (7.02)
Medicaid	48 (2.00)	192 (3.21)	248 (4.97)
Other/Uninsured	0 (0.00)	6 (0.10)	2 (0.04)
Smoking Status			
Never	1,932 (80.47)	4,529 (75.81)	3,440 (68.98)
Current	374 (15.58)	1,172 (19.62)	1,302 (26.11)
Former	95 (3.96)	273 (4.57)	245 (4.91)
Comorbidities			

ADI percentile	ADI 1		ADI 2		ADI 3
Obesity	341 (14.20)		1,068 (17.88)		1,033 (20.71)
Diabetes	7 (0.29)		39 (0.65)		23 (0.46)
Hypertension	1,101 (41.69)		2,576 (43.12)		2,310 (46.32)
Ischemic Heart Disease	1 (0.04)		2 (0.03)		3 (0.06)
Rheumatoid Arthritis	22 (0.92)		26 (0.44)		28 (0.56)
Hyperlipidemia	600 (24.99)		1,428 (23.90)		1,126 (22.58)
GERD	660 (27.49)		1,665 (27.87)		1,492 (29.92)
Cervical Myelopathy	716 (29.82)		1,678 (28.09)		1,557 (31.22)
Cervical Disc Herniation	1,776 (73.97)		4,343 (72.70)		3,581 (71.81)

ADI1 represents the least deprived areas and ADI3 represents the most deprived.

GERD=Gastroesophageal Reflux Disease

Table 3

Categorical Differences in Outcomes by Maryland Area Deprivation Index Tertile (2013–2020)

Parameter	ACDF rate per 100,000 adults (SD)	p value	total ACDF charges in inflation adjusted USD (SD)	p value
MD ADI Tertile				
ADI1	41.06 (27.67)	Referent	$21,496 (10,468)	Referent
ADI2	51.06 (30.58)	<0.001	$22,481 (10,934)	<0.001
ADI3	57.3 (25.23)	<0.001	$22,994 (15,213)	<0.001

ADI1 represents the least deprived areas and ADI3 represents the most deprived.

p values from ANOVA compared to ADI1

adults = 18 years or older

Table 4

Multivariate Regression Model Analyzing ACDF Utilization Rate per 100,000 Adults in Maryland (2013–2020)

Parameter	Coefficients (95% CI) in multivariate regression model predicting ACDF rate per 100,000 adults	p value
Maryland Area Deprivation Index Tertile		
ADI1	Referent	
ADI2	10.91 (9.65 to 12.18)	<0.001
ADI3	18.07 (16.76 to 19.39)	<0.001
Setting		
Inpatient	Referent	
Outpatient	4.59 (3.52 to 5.66)	<0.001
Age		
18–39	Referent	
40–64	−1.35 (−3.11 to 0.421)	0.135
>65	−1.62 (−3.51 to 0.272)	0.093
Sex		
Male	Referent	
Female	0.48 (−0.50 to 1.46)	0.336
Race		
White	Referent	
Black/African American	−12.31 (−13.36 to −11.26)	<0.001
Asian	−14.95 (−19.33 to −10.56)	<0.001
American Indian/Alaska Native	−15.16 (−24.75 to −5.58)	0.002
Hawaiian/Pacific Islander	−9.38 (−13.3 to −5.45)	<0.001
Multi-Racial	−7.47 (−17.56 to 2.62)	0.147
Other	−2.74 (−4.78 to −0.70)	0.009
Ethnicity		
Hispanic	Referent	
Non-Hispanic	9.81 (6.26 to 13.37)	<0.001
Declined/ Unknown	8.56 (4.46 to 12.66)	<0.001
Geographic Status		
Urban	Referent	
Rural	−26.51 (−28.49 to −24.52)	<0.001
Insurance Status		
Private	Referent	
Medicare	−2.82 (−6.09 to −1.67)	0.008
Medicaid	−7.48 (−8.03 to −2.84)	<0.001
Other/Uninsured	−8.68 (−25.96 to 13.84)	0.358
Smoking Status		

Parameter	Coefficients (95% CI) in multivariate regression model predicting ACDF rate per 100,000 adults	p value
Never	Referent	
Current	3.68 (2.49 to 4.88)	<0.001
Former	−1.71 (−4.05 to 0.63)	0.152
Comorbidities		
Obesity	1.99 (.73 to 3.25)	0.002
Diabetes	−3.74 (−10.54 to 3.06)	0.233
Hypertension	0.12 (−0.86 to 1.10)	0.814
Ischemic Heart Disease	−9.45(−30.81 to 11.90)	0.386
Rheumatoid Arthritis	4.02 (−2.02 to 10.07)	0.192
Hyperlipidemia	−1.00 (−2.08 to 0.076)	0.068
GERD	3.48 (2.40 to 4.56)	<0.001
Cervical Myelopathy	−1.80 (−2.90 to 0.70)	0.001
Cervical Disc Herniation	−3.28 (−4.53 to −2.01)	<0.001

adults = 18 years or older

ADI1 represents the least deprived areas and ADI3 represents the most deprived.

GERD=Gastroesophageal Reflux Disease

Table 5

Multivariate Regression Model Analyzing Hospital Charges in Inflation Adjusted USD

Parameter	Coefficients (95% CI) in multivariate regression model predicting ACDF charges	p value
Maryland Area Deprivation Index Tertile		
ADI1	Referent	
ADI2	930.66 (354.43 to 1506.88)	0.002
ADI3	1183.75 (581.99 to 1785.50)	<0.001
Setting		
Inpatient	Referent	
Outpatient	−3889.76 (−4397.53 to −3382.00)	<0.001
Age		
18–39	Referent	
40–64	1652.21 (890.996 to 2413.47)	<0.001
>65	3652.22(2815.05 to 4489.40)	<0.001
Sex		
Male	Referent	
Female	−699.82 (−1116.30 to −283.33)	0.001
Race		
White	Referent	
Black/African American	1102.00 (619.66 to 1584.34)	<0.001
Asian	−777.76 (−2775.19 to 1219.67)	0.445
American Indian/Alaska Native	1567.40 (−2788.68 to 5923.49)	0.481
Hawaiian/Pacific Islander	966.02 (−820.25 to 2752.28)	0.289
Multi-Racial	−1498.12 (−6086.49 to 3090.24)	0.522
Other	−355.90 (−1285.87 to 574.07)	0.453
Ethnicity		
Hispanic	Referent	
Non-Hispanic	374.30 (−1240.69 to 1989.29)	0.650
Declined/ Unknown	496.01 (−1369.84 to 2361.85)	0.602
Geographic Status		
Urban	Referent	
Rural	291.71 (−610.39 to 1193.820)	0.526
Insurance Status		
Private	Referent	
Medicare	1642.76 (696.46 to 2589.07)	0.001
Medicaid	2268.27 (1153.48 to 3383.06)	<0.001
Other/Uninsured	4407.06 (−4011.33 to 12825.44)	0.305
Smoking Status		
Never	Referent	

Parameter	Coefficients (95% CI) in multivariate regression model predicting ACDF charges	p value
Current	112.08 (−406.69 to 630.86)	0.672
Former	9136.59 (8098.03 to 10175.14)	<0.001
Comorbidities		
Obesity	−59.01 (−601.89 to 483.86)	0.831
Diabetes	2122.55 (−758.99 to 5004.09)	0.149
Hypertension	−133.48 (−574.18 to 307.22)	0.553
Ischemic Heart Disease	21089.81 (11380.59) to 30799.02)	<0.001
Rheumatoid Arthritis	−861.10 (3612.52 to 1890.32)	0.540
Hyperlipidemia	108.88 (−398.84 to 616.61)	0.674
GERD	−957.62 (−1423.92 to −491.33)	<0.001
Cervical Myelopathy	1374.87 (872.42 to 1876.96)	<0.001
Cervical Disc Herniation	−1145.33 (−1718.52 to −572.13)	<0.001

adults = 18 years or older

ADI1 represents the least deprived areas and ADI3 represents the most deprived.

GERD=Gastroesophageal Reflux Disease