ABSTRACT

Title of Dissertation:	NEIGHBORHOOD SOCIOECONOMIC STATUS, UTILIZATION AND SHORT-TERM POSTOPERATIVE OUTCOMES FOLLOWING BARIATRIC SURGERY IN MARYLAND
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Introduction: Bariatric surgery is an effective and evidence-based treatment for severe obesity; however, socioeconomic disparities in utilization and outcomes persist. This dissertation comprises three interrelated studies aimed at examining the impact of neighborhood socioeconomic status (nSES), as measured by the Distressed Communities Index (DCI), on bariatric surgery utilization and short-term postoperative outcomes in Maryland. The moderating role of race and ethnicity is also explored across these domains.

Methods: A cross-sectional analysis was conducted using the 2018–2020 Maryland State Inpatient Database, linked with ZIP code-level DCI data. Multivariable logistic regression models were used to assess associations between nSES and (1) bariatric surgery utilization, (2) post-operative complications, and (3) 30-day readmissions. Interaction terms were included to evaluate effect modification by race/ethnicity.

Results: Study I demonstrated that bariatric surgery utilization declined significantly with increasing neighborhood distress. Patients from distressed areas had 31% lower odds of undergoing bariatric surgery compared to those from prosperous neighborhoods (OR: 0.69, 95% CI: 0.63–0.76). Race significantly modified this association: Black individuals were more likely than White individuals to undergo surgery across all nSES levels, with the largest differences observed in the most distressed communities.

Study II found no statistically significant association between nSES and short-term postoperative complications, including gastrointestinal leaks, venous thromboembolism, and gastrointestinal bleeding. Race and ethnicity did not significantly modify these relationships.

Study III revealed no significant associations between nSES and healthcare quality measures, including prolonged hospital stays and readmissions. Similarly, no interaction effects were observed by race or ethnicity for these outcomes.

Conclusion: Neighborhood socioeconomic disadvantage was associated with reduced bariatric surgery utilization, particularly among individuals residing in distressed communities. However, nSES was not significantly associated with short-term surgical outcomes or healthcare quality metrics. Racial differences in surgery utilization persisted across all nSES levels, underscoring the importance of intersectional approaches to addressing inequities in access to bariatric surgery.

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List of Abbreviations

DCI: Distressed Communities Index

ADI: Area Deprivation Index

nSES: Neighborhood Socioeconomic Status

SES: Socioeconomic Status

SID: State Inpatient Database

BMI: Body Mass Index

NHANES: National Health and Nutrition Examination Survey

CMS: Centers for Medicare & Medicaid Services

IPPS: Inpatient Prospective Payment System

OPPS: Outpatient Prospective Payment System

HSCRC: Health Services Cost Review Commission

TCOC: Total Cost of Care

CRP: Care Redesign Program

HCIP: Hospital Care Improvement Program

CCIP: Complex and Chronic Care Improvement Program

BMI: Body Mass Index

SID: State Inpatient Database

VTE: Venous Thromboembolism

CCI: Charlson Comorbidity Index

STOP-CI: Short-Term Post-Operative Complication Index

GI: Gastrointestinal

GERD: Gastroesophageal Reflux Disease

MI: Multiple Imputation

MAR: Missing At Random

MCAR: Missing Completely at Random

SDOH: Social Determinants of Health

Chapter 1: Introduction and Literature Review

INTRODUCTION

Obesity is recognized as a chronic disease and a complex medical condition characterized by an abnormal or excessive accumulation of body fat that poses significant health risks and can lead to various complications[1-3]. Obesity prevalence in the United States has increased significantly since the 1960s, rising from 13% to 32% among adults by 2004[4] However, research by Kranjac et al. indicates that BMI and obesity rates remained relatively stable in the early-to-mid 1970s, before sharply increasing in the early 1980s[5]. From the 1980s onward, the prevalence of obesity surged dramatically, reflecting widespread changes in dietary habits, physical activity, and other environmental factors[6-8]. Data from the National Health and Nutrition Examination Survey (NHANES) show that the prevalence of obesity among adults increased from 30.5% in 1999 to 42.4% by 2018, highlighting the growing public health crisis[9-11]. Recent projections suggest that this upward trend is unlikely to slow without significant intervention, with estimates indicating that over 40% of the U.S. adult population is currently classified as obese[10]. Alarmingly, if current trends persist, it is predicted that more than half of the adult population (48.9%) will be classified as obese by 2030[10].

In the 1950s, the University of Minnesota marked a significant milestone in the field of obesity treatment by performing the first surgical procedure specifically designed for weight loss[12]. Since then, bariatric surgery has evolved considerably and is now widely regarded as the most effective and durable treatment for morbid obesity and its related comorbid conditions[13,14]. While various

nonsurgical approaches, such as dietary modifications, behavioral therapy, and pharmacotherapy, have been explored to manage obesity, multiple studies have consistently demonstrated their limited success in achieving sustained, long-term weight reduction when compared to bariatric surgery[15]. Bariatric procedures, including gastric bypass, sleeve gastrectomy, and adjustable gastric banding, offer profound and lasting weight loss, alongside substantial improvements in obesity-related health issues such as type 2 diabetes, hypertension, and sleep apnea[13,16-18]. These surgeries not only produce superior outcomes in terms of weight reduction but also significantly reduce the risk of mortality and improve quality of life in patients with severe obesity.

Disparities in Bariatric Surgery Utilization

Disparities in access to and utilization of bariatric surgery are well-documented, with socioeconomic status (SES), race/ethnicity, and geographic location playing significant roles in shaping who undergoes surgery[19-22]. Multiple studies have highlighted that individuals from racial and ethnic minority groups are less likely to receive bariatric surgery compared to White individuals, even after adjusting for factors such as insurance status and clinical eligibility[19,21]. Similarly, individuals with lower educational attainment and lower household incomes are less likely to undergo surgery despite being medically eligible[23-25].

The barriers contributing to these disparities are multifaceted. Cultural perceptions of obesity and weight loss, differential access to healthcare providers, and insurance coverage limitations may all contribute to lower utilization among certain groups[20,26]. Additionally, geographic disparities exist, with individuals residing in rural or medically underserved areas having less access to specialized bariatric centers, further reducing the likelihood of undergoing surgery[20,21,27].

In a recent systematic review, Black and Hispanic patients were found to be significantly underrepresented in bariatric surgery cohorts, accounting for only a small proportion of the total procedures performed nationwide[26,28]. This underrepresentation is concerning given the high prevalence of obesity and obesity-related comorbidities within these communities. Potential explanations include differences in referral patterns, lower levels of health literacy, and provider biases in recommending bariatric surgery[21,26]. Addressing these disparities requires a nuanced understanding of the social determinants of health, including neighborhood characteristics that go beyond individual-level factors.

Neighborhood Socioeconomic Status and Health Outcomes

Neighborhood socioeconomic status (nSES) encompasses the broader social and economic environment in which individuals reside[29,30]. It reflects not only individual income or education but also collective community resources, social cohesion, and access to services. Measures of nSES typically include indicators such as median household income, poverty rates, educational attainment, employment rates, and housing conditions[29,31]. These indicators are often aggregated into indices, such as the ADI and the DCI, to provide a comprehensive measure of neighborhood deprivation[32,33].

Lower nSES has been linked to worse health outcomes across a range of conditions, including cardiovascular disease, cancer, and diabetes[29,34]. The mechanisms through which nSES affects health outcomes are complex and may include reduced access to healthcare services, environmental stressors, and lower availability of health-promoting resources such as parks, recreational facilities, and healthy food options[31,35]. For surgical procedures, lower nSES has been associated with increased rates of post-operative complications, prolonged hospital stays,

and higher rates of readmissions[32,36,37]. These associations suggest that neighborhood factors may influence not only access to surgery but also the quality of care and recovery experiences.

Neighborhood Socioeconomic Status and Healthcare Utilization

Healthcare utilization is heavily influenced by both individual and neighborhood-level factors[38]. Individuals from lower SES backgrounds are generally less likely to access preventive healthcare services and more likely to present with advanced stages of disease[29,39]. In the context of elective surgeries, such as bariatric surgery, nSES plays a critical role in shaping access and utilization patterns. Patients from socioeconomically deprived neighborhoods are less likely to receive referrals for elective surgeries and may face additional barriers such as transportation difficulties, lack of support networks, and financial constraints that hinder their ability to seek surgical care[32,36,40,41].

The literature suggests that neighborhood deprivation is associated with delayed healthcare utilization, higher emergency department use, and lower use of specialist services[32,36]. These patterns are particularly evident in areas with limited healthcare infrastructure, where residents may have to travel long distances to access care[42,43]. In addition, patients from more deprived neighborhoods experienced worse outcomes after common surgical procedures, which could be related to the quality of hospitals in different areas[36].

Bariatric Surgery and Neighborhood Socioeconomic Status

The impact of nSES on bariatric surgery utilization and outcomes is an emerging area of research. While studies have explored the relationship between individual SES and surgical outcomes[36,44,45], few have focused on the broader neighborhood context. A recent study by

Murtha et al, utilizing single unit hospital data in a predominantly white population, using the ADI reported that individual patient characteristics have a stronger association with weight loss outcomes compared to neighborhood-level social determinants and lifestyle factors[46]. However, these findings are limited by small sample sizes and a lack of consideration for racial and ethnic interactions. These findings go against results reported by others in literature who found the opposite in other surgical conditions such as colorectal surgeries[32,36]. The inconsistent and often limited findings regarding the impact of neighborhood socioeconomic status on bariatric surgery utilization and short-term outcomes highlight the need for further research to better understand this relationship. Individuals living in poor neighborhoods are more likely to experience higher hospital readmission rates[47], increased obesity prevalence[48] , worse outcomes after colon and rectal surgeries[32], and higher rates of missed pre- and post-operative appointments. Although Murtha et al did not find a significant association between the ADI and weight loss following bariatric surgery[46], research indicates that individuals from lower socioeconomic backgrounds have lower rates of undergoing bariatric surgery and face more barriers to accessing healthcare, transportation, and nutritious food[23,49].

The Distressed Communities Index

The variable of interest in this analysis was the DCI, utilized as a tool to measure community-level socioeconomic deprivation. Developed by the Economic Innovation Group (EIG), the DCI quantifies neighborhood socioeconomic risk through seven metrics that collectively capture economic and social vulnerabilities[50]. These metrics include: the proportion of the population (age ≥ 25 years) without a high school diploma or equivalent, the rate of vacant housing units (adjusted for recreational, seasonal, or occasional use vacancies), and the proportion of the

working-age population (ages 25-54) not engaged in the labor force (either unemployed or not actively seeking work)[51]. Additional metrics cover the proportion of residents living below the federal poverty line, the median household income as a percentage of the median income in the corresponding metro area or state, and recent changes in both the number of employees and business establishments within the ZIP code[51,52].

From these inputs, the DCI generates scores ranging from 0 (no distress) to 100 (severe distress), calculated by ranking ZIP codes on each metric, averaging them, and normalizing the data to produce a relative measure of socioeconomic distress[51]. Based on these scores, American communities are classified into five tiers of socioeconomic status: prosperous, comfortable, mid-tier, at-risk, and distressed[53].

Unlike other indices, such as the Area Deprivation Index (ADI)[54] or the Social Vulnerability Index (SVI)[55], which primarily measure deprivation through individual level indicators of education, income, and housing quality, the DCI[53] uniquely incorporates dynamic elements, like business establishment growth and employment trends, that highlight economic cycles and resilience within communities. This comprehensive, tiered approach allows the DCI to offer a more nuanced view of socioeconomic landscapes, aiding policymakers, researchers, and the public in identifying areas most in need of intervention and resource allocation

The DCI, which incorporates community-level economic metrics such as business vitality and job growth, may offer additional insights into how economic conditions at the community level influence surgical access and outcomes[56]. The Economic Innovation Group (EIG)[57], a bipartisan public policy organization established in 2013, aims to tackle critical economic challenges in the United States through innovative research and data-driven advocacy. As part of its efforts, EIG

developed the DCI, which provides a composite ranking of socioeconomic distress by ZIP code. The DCI is based on seven key indicators: unemployment, education level, poverty rate, median household income, number of business establishments, job growth, and housing vacancy rates. This index has been validated as an effective tool for assessing the level of socioeconomic distress within communities[58]. This measure is particularly useful for identifying areas where social and economic disadvantages may impact health outcomes and access to resources, making it a valuable tool for research focused on health disparities and community-level factors affecting public health. There is a need for more research that incorporates both individual- and neighborhood-level factors to fully understand the complex interplay between nSES and health outcomes following bariatric surgery.

The Maryland Global Budget Payment System

On January 1, 2014, Maryland launched an innovative All-Payer Model[59], transitioning the state's hospital payment structure to an all-payer, annual global budget system covering almost all inpatient and outpatient hospital services. Building on Maryland's legacy of pioneering healthcare payment reform, which began in the 1970s with a regulated all-payer hospital rate-setting system, the All-Payer Model was developed in partnership with the Centers for Medicare & Medicaid Services (CMS). This model set Maryland apart from other states by exempting its hospitals from Medicare's standard Inpatient Prospective Payment System (IPPS) and Outpatient Prospective Payment System (OPPS), contingent on Maryland keeping Medicare inpatient cost growth below the national rate. However, as Maryland’s cost per admission outpaced the national trend, the state risked losing its exemption[59]. Additionally, the old model’s focus on payment per admission conflicted with contemporary healthcare reforms prioritizing coordinated, value-based care.

In response, Maryland proposed a model that capped total hospital revenues through global budgets rather than individual admissions[60]. By July 2014, all 46 general acute care hospitals in Maryland adopted global budgets, covering 95% of hospital revenue[59]. Although new to most, global budgets had been piloted in 10 rural hospitals under the earlier Total Patient Revenue (TPR) program[59]. Maryland's agreement with CMS required the state to achieve specific goals over five years:

1. **Readmission and Complication Reduction**: Maryland aimed to match the national 30-day readmission rate and reduce preventable complications by 30%[59].
2. **Total Cost of Care (TCOC) Limits**: Annual growth in per-beneficiary TCOC for Maryland's Medicare population could not exceed the national rate by more than 1% in any given year, with growth capped at or below the national rate in at least one of every two years[59].
3. **Population Health Reporting**: Maryland was required to submit annual reports on various health outcomes to CMS[59].

Each hospital's budget was set based on 2013 revenues, adjusting annually for inflation, volume changes due to population shifts, and other factors like reductions in avoidable hospital use (e.g., readmissions), quality improvements, and uncompensated care adjustments[59]. The Health Services Cost Review Commission (HSCRC) then set uniform service rates that Maryland hospitals used to bill all payers, with a 6% discount for Medicare and Medicaid, which had been in place before the model's implementation[61]. Although revenue caps applied to most services for both Maryland and out-of-state residents, hospitals could earn additional revenue outside the global budget for services like home health, outpatient renal dialysis, and skilled nursing[59].

Hospitals were incentivized to stay within budget. If actual utilization deviated from projections, causing revenues to differ from the global budget, the HSCRC adjusted the next year's budget to compensate for underages or recoup overages[59]. Overages or underages exceeding 0.5% of the hospital budget were penalized to deter chronic overcharging or undercharging. Since exact alignment with utilization forecasts was challenging, hospitals were allowed rate adjustments within a 5% margin to meet their budget, with stricter limits requiring HSCRC approval[59].

The All-Payer Model also marked the first step toward a population-based payment model. Maryland's agreement with CMS required it to transition by 2019 to a model focusing on per capita TCOC across all healthcare services, not just hospital costs. To facilitate this shift, Maryland introduced the Care Redesign Program (CRP) in 2017[60]. The CRP's two tracks, the Hospital Care Improvement Program (HCIP) and Complex and Chronic Care Improvement Program (CCIP), allowed hospitals to coordinate with community providers to improve patient transitions and manage high-cost, complex patients[59].

Maryland successfully met the All-Payer Model's terms by 2019, paving the way for the Total Cost of Care (TCOC) Model[59]. The TCOC Model retained hospital global budgets, expanded the CRP to include a third track focused on bundled payments for episodes of care, and introduced the Maryland Primary Care Program. This new program supports primary care providers in delivering advanced care and aligns incentives with TCOC goals, further driving Maryland's shift to a statewide, value-based care model that controls total healthcare costs[62].

Conducting this present research using the Maryland SID provides comprehensive, uniform data on all hospital admissions across the state, eliminating payer-based disparities[63]. Its global budget system reduces financial incentives to increase surgical volumes, allowing analysis of

utilization patterns based on true patient needs. The model's emphasis on reducing preventable admissions and complications aligns with our goal of evaluating short-term postoperative outcomes, especially for individuals living in lower-SES neighborhoods. Additionally, incentives for quality improvements and resources allocated to at-risk populations support equitable care[64]. Together, these factors make Maryland's model ideal for studying nSES-related disparities in bariatric surgery access and outcomes.

Theoretical Framework: Andersen's Behavioral Model of Health Services Use

The Andersen Behavioral Model of Health Services Use provides a structured approach to understanding how various factors influence healthcare utilization by categorizing them into predisposing characteristics, enabling resources, and need factors. This model, initially developed in the 1960s by Ronald Andersen, emphasizes that healthcare-seeking behaviors are not only determined by individual needs but are shaped by broader social and environmental contexts[65,66].

Predisposing characteristics include demographic factors (age, gender, race) and social structures like socioeconomic status (SES), which play a role in determining healthcare behaviors[66,67]. Higher-SES individuals or those from affluent neighborhoods may have more favorable health-seeking behaviors and support networks, which can increase healthcare access and willingness to seek elective interventions, such as bariatric surgery[68,69].

Enabling resources refer to the financial, community, and healthcare system resources that facilitate access to care. These include individual resources (e.g., income, health insurance) and neighborhood-level resources, like proximity to healthcare facilities and specialist availability, which influence whether individuals can realistically access needed services. Lower-SES

neighborhoods may lack these resources, hindering access to bariatric surgery despite medical necessity[49].

Need factors represent both perceived and evaluated health needs, such as severe obesity, which drives demand for bariatric surgery. While need factors typically signal when care is warranted, perceptions around these needs shaped by SES can alter the likelihood of seeking or prioritizing care[24]. The Andersen Model thus provides a comprehensive framework for evaluating how neighborhood SES may influence both the decision to pursue bariatric surgery and subsequent health outcomes.

Study Rationale

The rationale for this study is based on the growing recognition that neighborhood context matters for health outcomes. Despite substantial evidence linking nSES to various health outcomes, its role in bariatric surgery utilization, short-term postoperative outcomes and on healthcare quality measures such as prolonged hospital stay and readmissions is not well understood. Given the increasing prevalence of obesity and the recognized disparities in surgical care, this study addresses a critical gap by focusing on the independent effect of nSES on bariatric surgery in Maryland. The findings of this study will inform future interventions to reduce disparities and improve the quality of care for vulnerable populations.

Project Narrative

Obesity affects nearly 42% of U.S. adults aged 20 and older[70] and is linked to chronic diseases such as hypertension, diabetes, and heart failure, which contribute significantly to morbidity and mortality[71,72]. Severe obesity (BMI > 40) exacerbates these risks, driving up

healthcare costs and straining public health resources, with an estimated annual economic impact exceeding $260.6 billion as of 2016[73]and $347.5 billion in 2023[74]. Bariatric surgery provides effective, sustained weight loss and improves obesity-related health conditions when lifestyle changes and medical treatments are insufficient. However, access to and outcomes of bariatric surgery are not equally available across all populations, with neighborhood socioeconomic status (nSES) playing a crucial role in influencing who undergoes surgery and their short-term postoperative outcomes.

This study hypothesizes that neighborhood SES is a significant factor in bariatric surgery utilization and outcomes, with individuals from low-SES neighborhoods facing greater barriers to surgery access and poorer postoperative outcomes. Guided by Andersen's Behavioral Model of Health Services Use, this study will evaluate how neighborhood SES impacts surgery rates, complications (such as gastrointestinal leaks and venous thromboembolism), and healthcare quality measures (Prolonged hospital stays and readmissions) among patients in Maryland, utilizing the Maryland State Inpatient Database. Additionally, it will utilize the ADI, which has been a gold standard for measuring nSES as a sensitivity check on the findings generated by utilizing the DCI as a measure of nSES in this study.

Specific Aims

Obesity affects 42% of U.S. adults of adults aged 20 and older[70] and is linked to chronic conditions like hypertension, diabetes, and heart failure, leading to increased morbidity and premature mortality[75-78]. Severe obesity (BMI > 40) poses even greater health risks[79]. The economic impact exceeds $140 billion annually, including direct medical expenses and indirect costs such as lost productivity and absenteeism[80]. Bariatric surgery is the most effective treatment for

severe obesity, leading to sustainable weight loss and improved comorbidities like diabetes and heart disease when lifestyle and medical therapies are insufficient[81,82] [7-8]. Procedures such as gastric bypass and sleeve gastrectomy also lower long-term healthcare costs by enhancing quality of life and reducing the need for medication and hospitalizations[83]. However, disparities in access to and outcomes following bariatric surgery are not equitably distributed across populations.

Neighborhood socioeconomic status (nSES), independent of individual SES and race, plays a critical role in determining who undergoes surgery and influences post-surgical outcomes[49,84]. For example, individuals in socioeconomically deprived neighborhoods are less likely to receive bariatric surgery despite eligibility[46]. This disparity is linked to limited access to resources, opportunities, and systemic barriers present in these neighborhoods. There is evolving evidence that structural and systemic factors concentrated in socioeconomically deprived neighborhoods are associated with worse outcomes. Additionally, incorporating nSES indicators with disease risk factors significantly improves the accuracy of models predicting disease outcomes, highlighting the need for a comprehensive approach to address these inequities[85-88].

Few studies have explored the impact of nSES on bariatric surgery utilization and short-term post-operative outcomes. Most research focuses on long-term outcomes, like weight loss, or examines neighborhood factors such as food deserts[46]. The use of indices like the ADI and the DCI to assess disparities in bariatric surgery is limited and understudied in the literature. The ADI has been the standard for measuring nSES using 17 individual-level socioeconomic indicators. The more recent DCI however utilized both individual-level socioeconomic indicators and additional community-level economic metrics that measures business vitality potentially enhancing diagnostic accuracy by capturing broader community-level economic dynamics[57,89].

This study will utilize the Andersen's Behavioral Model of Health Services Use to evaluate how nSES influences bariatric surgery utilization and short-term post-operative outcomes among adults with severe obesity in Maryland. Maryland's All-Payer Model reduces variability in cost and access to surgical services, making it a particularly compelling environment for this study[90]. I will use the Maryland SID, (2018-2022) for this study with analysis focusing on all individuals aged 18 and above eligible for bariatric surgery. The specific aims are as follows:

Aim 1. To assess if there is an independent association between nSES and the proportion of eligible patients undergoing bariatric surgery in Maryland.

- Hypothesis 1a: Patients from neighborhoods with lower nSES will be less likely to undergo bariatric surgery compared to those from higher nSES neighborhoods.
- Hypothesis 1b: The interaction between race/ethnicity and nSES will significantly influence the likelihood of undergoing bariatric surgery with minority groups such as Blacks and Hispanics living in the poorest neighborhoods having the lowest utilization rates.

Aim 2. To evaluate the independent association between nSES and post-operative complications after bariatric surgery, including gastrointestinal leaks, surgical site infections, and venous thromboembolisms (VTE).

- Hypothesis 2a: Lower nSES will be associated with higher rates of gastrointestinal leaks.
- Hypothesis 2b: Lower nSES will be associated with higher rates of gastrointestinal bleeding.
- Hypothesis 2b: Lower nSES will be associated with higher rates of VTE.

- Hypothesis 2c: The interaction between race/ethnicity and nSES will significantly influence the rates of gastrointestinal leaks, bleeding and VTE with minority groups such as Blacks and Hispanics living in the poorest neighborhoods having the highest complication rates.

Aim 3. To evaluate the independent association between nSES and healthcare quality measures such as prolonged hospital stays and readmissions.

- Hypothesis 3a: Lower nSES will be associated with longer hospital stays.
- Hypothesis 3b: Lower nSES will be associated with higher risk of hospital readmissions.
- Hypothesis 3c: The interaction between race/ethnicity and nSES will affect the association between nSES and both prolonged hospital stays and readmissions with minority groups such as Blacks and Hispanics living in the poorest neighborhoods having the highest healthcare resource utilization rates

Chapter 2: PAPER 1: Bariatric Surgery Utilization

Variation of Bariatric Surgery Utilization by Neighborhood Socioeconomic Status in Maryland

ABSTRACT

Introduction: Bariatric surgery is an effective treatment for severe obesity; however, significant disparities persist in its utilization, particularly among socioeconomically disadvantaged populations. The influence of neighborhood socioeconomic status (nSES) on bariatric surgery utilization remains understudied.

Objective: This study examines the association between nSES and bariatric surgery utilization in Maryland and evaluates whether this relationship varies by race and ethnicity.

Methods: We conducted a cross-sectional analysis using data from the Maryland State Inpatient Database (2018–2020), linked with the Distressed Communities Index (DCI). Adults aged ≥18 years with a BMI ≥35 kg/m² were considered eligible for bariatric surgery. nSES was categorized into five tiers: prosperous, comfortable, mid-tier, at-risk, and distressed. Race and ethnicity were self-reported and classified as non-Hispanic White, non-Hispanic Black, Hispanic, and Other. Multivariable logistic regression models, adjusted for age, sex, race/ethnicity, insurance status, comorbidities, obesity class, and urbanicity, were used to assess the association between nSES and surgery utilization. Interaction terms evaluated potential effect modification by race and ethnicity.

Results: Among 154,665 eligible individuals, only 10,784 (7.0%) underwent bariatric surgery. Most recipients were female (83.2%), with Black (48.3%) and White (44.8%) individuals

comprising the largest racial groups. A socioeconomic gradient was evident: individuals from distressed neighborhoods had 30% lower odds of undergoing surgery (OR: 0.70; 95% CI: 0.64–0.76) compared to those from prosperous areas. The odds were similarly reduced for those in mid-tier (OR: 0.74; 95% CI: 0.70–0.79), at-risk (OR: 0.89; 95% CI: 0.83–0.96), and comfortable (OR: 0.89; 95% CI: 0.84–0.95) neighborhoods. Race significantly modified this relationship: Black individuals were more likely than White individuals to undergo surgery across all DCI quintiles, with marginal effects ranging from 0.90% in prosperous to 2.10% in distressed areas.

Conclusions: Bariatric surgery remains underutilized, especially among individuals residing in socioeconomically distressed neighborhoods. However, race moderates this association, with Black individuals consistently exhibiting higher utilization than White individuals across all levels of neighborhood socioeconomic status.

Implications: Interventions aimed at improving bariatric surgery access should focus on reducing structural barriers in disadvantaged neighborhoods. Culturally informed outreach strategies and equitable referral systems may enhance utilization, particularly among historically underserved racial and ethnic groups.

INTRODUCTION

Severe obesity represents a significant public health challenge, with far-reaching implications for individual health, healthcare systems, and societal well-being[91,92]. Bariatric surgery, also known as weight loss surgery, has emerged as an effective and evidence-based intervention for managing severe obesity and its associated comorbidities[16,93]. By providing sustained weight loss, improved metabolic profiles, and enhanced quality of life, bariatric surgery has proven to be a critical treatment for patients who meet the eligibility criteria of body mass index (BMI) thresholds with coexisting medical conditions[94]

Although the impact of individual income on disparities in healthcare access and health outcomes is well-established, the role of neighborhood socioeconomic status (nSES) is gaining recognition as a significant determinant of health [95,96]. The cumulative effects of social and economic disadvantage in distressed neighborhoods can influence health behaviors, access to healthcare, and ultimately, the utilization of critical services such as bariatric surgery[23,97]. Measures like the Distressed Communities Index (DCI) provide a comprehensive framework for assessing nSES, categorizing neighborhoods based on economic, social, and health metrics[58,98,99]. However, the association between nSES and bariatric surgery utilization, particularly when accounting for potential modifiers like race and ethnicity, remains underexplored.

Racial and ethnic disparities in socioeconomic status, healthcare access, and insurance coverage further contribute to inequities in bariatric surgery utilization [19,100]. Black and Hispanic populations, who disproportionately reside in socioeconomically disadvantaged neighborhoods, face structural barriers that limit access to surgical care [101,102]. Although bariatric surgery is typically covered by public and private insurance, reimbursement policies may still pose

challenges for both patients and providers[103-105]. Patients often face variable out-of-pocket costs depending on their insurance plan, and low-income individuals may delay or forgo surgery due to upfront expenses[106]. In addition, declining reimbursement rates for bariatric procedures such as the 32.8% decrease for sleeve gastrectomy between 2010 and 2022 may discourage provider availability or limit surgical capacity in underserved areas[107,108]. Understanding the interplay between nSES and race and ethnicity is critical for addressing these disparities and ensuring equitable access to bariatric surgery.

This study aims to evaluate the association between neighborhood socioeconomic status (nSES) and bariatric surgery utilization in Maryland, a state characterized by demographically diverse populations and significant socioeconomic variation across communities. As of recent data, approximately 34.3% of adults in Maryland were classified as obese, which is slightly above some reported national averages but consistent with broader trends of rising obesity rates across the U.S[109]. Maryland is located in a region known for its high utilization of bariatric surgery, reflecting both a significant disease burden and active engagement in surgical obesity treatment. This regional trend suggests a strong commitment to addressing obesity through surgical interventions[110]. Using data from the 2018–2020 Maryland State Inpatient Database (SID) merged with DCI scores, this study investigates the extent to which nSES influences the likelihood of undergoing bariatric surgery among eligible patients. Furthermore, the study examines whether race and ethnicity modifies this association, providing insights into the nuanced ways socioeconomic and racial factors intersect to shape healthcare access Furthermore, the study examines whether race and ethnicity modify this association. We hypothesize that patients from more distressed neighborhoods will be less likely to undergo bariatric surgery, and that this relationship will vary by race and ethnicity—such that racial and ethnic minorities in

highly distressed areas may experience different patterns of access or utilization compared to their White counterparts.

METHODOLOGY

Study Design

This study utilized a cross-sectional design to evaluate the relationship between nSES, as measured by the (DCI, and the likelihood of bariatric surgery utilization among eligible patients in Maryland. The analysis also investigated the interaction between race and ethnicity and nSES in influencing bariatric surgery utilization. The cross-sectional design is appropriate for assessing population-level associations at a specific time point and is consistent with the study objectives.

Data Source

Data for this study were derived from the Maryland State inpatient datasets[111], a comprehensive statewide administrative dataset that integrates hospital discharge records, demographic information, and socioeconomic indicators. The dataset includes all eligible patients undergoing bariatric surgery in Maryland from January 1, 2018, to December 31, 2020. The Distressed Communities Index (DCI) data[112] was linked to patient-level records based on residential ZIP codes. The DCI encompasses metrics such as poverty rates, housing vacancy, educational attainment, and income inequality, providing a robust composite measure of neighborhood distress. The Distressed Communities Index (DCI) is a composite measure developed by the Economic Innovation Group (EIG) in 2013[112]. It evaluates socioeconomic deprivation at the community level, focusing on the economic health and vulnerabilities of neighborhoods across the United States. The DCI is widely recognized for its ability to quantify the socioeconomic

well-being of ZIP code-level communities using seven key metrics and has been used in several prior studies examining the impact of neighborhood socioeconomic status and health outcomes[58,110].

The DCI integrates seven core metrics that collectively capture economic and social vulnerabilities[111]. These include the percentage of adults aged 25 years and older without a high school diploma or equivalent, the proportion of vacant housing units adjusted for seasonal, recreational, or occasional use, and the percentage of the working-age population (ages 25-54) not engaged in the labor force, which includes both unemployed individuals and those not actively seeking work. Additional metrics cover the percentage of residents living below the federal poverty line, the median household income as a percentage of the median income in the corresponding metro area or state, and changes in both the number of business establishments and employed individuals within the ZIP code over a specified period. These metrics are normalized and ranked to generate a DCI score for each community, with scores ranging from 0 (no distress) to 100 (severe distress), representing a relative measure of socioeconomic disadvantage[106,112].

Study Population

The study population consisted of adults aged 18 years and above who are eligible for bariatric surgery based on clinical guidelines, including a body mass index (BMI) ≥40 kg/m² or BMI ≥35 kg/m² with comorbid conditions[83]. Patients were identified using International Classification of Diseases, 10th Revision (ICD-10) procedure codes specific to bariatric surgery. This study included adults aged 18 years or older who met clinical guidelines for bariatric surgery eligibility and were Maryland residents, as identified by ZIP code.

Explanatory Variable

The DCI can be operationalized in two forms: as a continuous variable and as a categorical variable. Each community is assigned a DCI score based on its performance across the seven metrics, which serves as a granular measure of socioeconomic distress and enables comparisons across ZIP codes and regions. Alternatively, the DCI is categorized into five distinct tiers based on percentile rankings of ZIP codes. These tiers include Prosperous (0th to 20th percentile), Comfortable (21st to 40th percentile), Mid-Tier (41st to 60th percentile), At-Risk (61st to 80th percentile), and Distressed (81st to 100th percentile). This categorical operationalization facilitates the identification of trends and disparities within socioeconomic strata and simplifies interpretation for policy development and public health research.

Outcome Variable

The outcome, bariatric surgery utilization, was defined as undergoing any bariatric procedure during the study period. Bariatric procedures were identified using ICD-10 procedure codes (see Appendix), which included Roux-en-Y gastric bypass, sleeve gastrectomy, and other approved bariatric interventions. This variable was binary, coded as 1 for patients who underwent surgery and 0 for those who did not.

Covariates

Covariates included individual-level demographic and clinical variables to control for potential confounders. Age was modeled as both a continuous and a categorical variable. As a continuous variable, it was defined for individuals aged 18 years and older. As a categorical variable, age was classified into three groups: 18–44 years (reference group), 45–64 years, and ≥65 years.

Other. Moreover, sex was categorized as male or female. Race and ethnicity were classified into four groups: White, Black, Hispanic, and Other. The Other category included individuals identified as Asian/Pacific Islander, Native American, multiracial or mixed race, and those who did not report or declined to state their race or ethnicity. Insurance type was categorized as self-pay, Medicare, Medicaid, private insurance, or other, based on the primary payer listed at the time of hospitalization. In cases where patients had multiple forms of coverage, the primary source of insurance was used for classification in this study. Obesity class was defined according to BMI thresholds: Class I (BMI 30–34.9), Class II (BMI 35–39.9), or Class III (BMI ≥40). Individuals classified as BMI Class I were excluded, as they did not meet the eligibility criteria for bariatric surgery. The Charlson Comorbidity Index (CCI) was included as a measure of overall health status and was categorized into three levels: 0, 1–2, or greater than 2. Finally, the year of surgery was included as a covariate to account for temporal trends in bariatric surgery utilization.

Statistical Analysis

Baseline characteristics of the study population were summarized using frequencies and percentages for categorical variables. Differences between patients undergoing bariatric surgery and those who did not were assessed using chi-square tests for categorical variables and t-tests for continuous variables.

Logistic regression models are employed to estimate the association between neighborhood socioeconomic status (nSES) and likelihood of bariatric surgery utilization among eligible individuals. The primary explanatory variable, nSES, is measured using the DCI, which is included in the models as both a continuous variable and a categorical variable. Covariates are

incrementally added across four sequential models to control for potential confounders. Model 1 examines the unadjusted association between DCI and bariatric surgery utilization. Model 2 incorporates demographic variables, including age (continuous), sex (male or female), and race and ethnicity (White, Black, Hispanic, Asian/Pacific Islander, Native American, or Other). Model 3 further adjusts for clinical factors, including obesity class (Class I, II, or III), the Charlson Comorbidity Index (categorized as 0, 1–2, or >2), and insurance type (self-pay, Medicare, Medicaid, private insurance, or other). Model 4 includes socioeconomic covariates and insurance types.

An interaction term between race/ethnicity and the Distressed Communities Index (DCI) quintiles was incorporated to assess whether the association between neighborhood socioeconomic status (nSES) and bariatric surgery utilization varies across racial and ethnic groups. To appropriately interpret this interaction within a nonlinear logit model, we employed marginal effects at representative values using the margins command in Stata. This method estimates the change in the predicted probability of bariatric surgery utilization for each racial/ethnic group across DCI quintiles, relative to the reference category. The results are presented as average marginal effects, which provide a more interpretable measure of the interaction than raw model coefficients in nonlinear models. This approach is supported by methodological literature emphasizing the importance of marginal effects for interpreting interactions in nonlinear models, where coefficients cannot be directly interpreted in the same manner as in linear models[113,114]. A statistically significant interaction effect suggests that the relationship between nSES and bariatric surgery utilization differs by race and ethnicity, underscoring the need for intersectional approaches to understanding healthcare disparities.

The final model specification is as follows:

$\text{Logit}(P(Y=1)) = \alpha + \beta1(\text{DCI}) + \beta2(\text{Covariates}) + \beta3(\text{Race}) + \beta13(\text{Race x DCI})$, where Y represents bariatric surgery utilization, α is the intercept, and $\beta13$ captures the interaction effect of race/ethnicity and DCI.

Several sensitivity analyses were performed to evaluate the robustness of the study's findings. These included re-assessing the relationship between DCI and bariatric surgery utilization using alternative categorizations of DCI (e.g., using DCI as a continuous variables) and propensity score matching to address potential selection bias. Additionally, the Area Deprivation Index (ADI) was used as an alternative measure of neighborhood SES to confirm the consistency of findings.

Ethical Considerations

This study utilized de-identified administrative data and was exempt from Institutional Review Board (IRB) oversight by the University of Maryland Institutional Review Board (2284677-1).

RESULTS:

Baseline Characteristics

Of the 154,665 individuals eligible for bariatric surgery in Maryland, demographic and clinical characteristics varied significantly across the five DCI quintiles (Table 1). Individuals in more distressed communities were younger, with the mean age declining from 58.1 ± 15.8 years in prosperous neighborhoods to 54.4 ± 15.2 years in distressed areas ($p < 0.001$). The proportion of individuals aged 18–44 was highest in distressed communities (26.6%) and lowest in prosperous

communities (19.7%), while the reverse was true for those aged ≥65 years (28.4% vs. 40.0%, (Table 1).

Women comprised a greater share of the population in distressed areas (69.5%) compared to prosperous ones (61.7%) ($p < 0.001$). Racial distribution differed markedly by DCI quintile: Black individuals were disproportionately represented in distressed areas (61.9%) and underrepresented in prosperous ones (24.6%), while White individuals made up 69.7% of those in prosperous areas compared to 35.5% in distressed areas ($p < 0.001$).

Insurance coverage also varied across quintiles. Private insurance was more common in prosperous (41.2%) and comfortable (36.9%) neighborhoods, while Medicaid coverage increased with socioeconomic distress—from 11.8% in prosperous areas to 31.7% in distressed communities ($p < 0.001$). Medicare utilization was relatively consistent across groups. Higher comorbidity burden (Charlson Comorbidity Index >2) was more prevalent in distressed communities (65.4%) compared to prosperous ones (61.5%) (Table 1).

Obesity class distribution revealed that Class II obesity was more common in distressed communities (64.4%) versus prosperous ones (56.2%), while Class I obesity followed the opposite pattern (35.6% vs. 43.8%) ($p < 0.001$). Lastly, geographic distribution showed stark contrasts, with urban residents predominantly from distressed areas (67.8%) and suburban residents mainly from prosperous (77.8%) and comfortable (80.1%) communities. Rural and small-town residents were least represented in distressed communities (1.5% and 15.8%, respectively; Table 1).

Baseline Characteristics of Bariatric Surgery Eligible Individuals by Utilization Status

Among 154,665 individuals eligible for bariatric surgery in Maryland, only 7.0% (n = 10,784) underwent the procedure, while 93.0% (n = 143,881) did not (Table 2). Patients who received surgery were significantly younger, with a mean age of 44.1 ± 11.6 years, compared to 57.2 ± 15.8 years among non-utilizers ($p < 0.001$). Over half (52.5%) of those who underwent surgery were aged 18–44 years, whereas only 22.0% of non-utilizers fell in this age range. In contrast, 36.0% of non-utilizers were aged ≥65, compared to just 4.5% of those who had surgery (Table 2).

Surgical utilization also varied by neighborhood socioeconomic status (DCI). Individuals from prosperous (24.5%) and comfortable (28.6%) neighborhoods were more likely to undergo surgery than those from distressed neighborhoods (12.6%; $p < 0.001$).

Racial and ethnic disparities were evident. Black individuals comprised 48.3% of surgery recipients compared to 40.0% of non-utilizers, while White individuals made up a smaller proportion of the surgery group (44.8%) compared to non-utilizers (54.3%; $p < 0.001$).

Insurance coverage patterns differed substantially between groups ($p < 0.001$). Surgery patients were far more likely to have private insurance (70.1%) compared to non-utilizers (30.6%), and far less likely to be covered by Medicare (9.0% vs. 46.2%).

Women were significantly more likely to undergo surgery, accounting for 83.2% of the surgery group compared to 64.1% of non-utilizers (Table 2).

Patients who underwent surgery had fewer comorbidities. Only 36.3% had a Charlson Comorbidity Index (CCI) >2, compared to 64.3% of non-utilizers ($p < 0.001$). Conversely, 30.0% of surgery patients had no comorbidities (CCI = 0), compared to 15.4% of non-utilizers.

Regarding obesity classification, Class III obesity was more prevalent among surgery recipients (78.3%) than non-utilizers (58.3%; $p < 0.001$).

Geographic distribution differed slightly across groups, with statistical significance but limited clinical differences. Suburban residence was the most common in both groups (67.5% among utilizers vs. 66.2% among non-utilizers; Table 2).

Factors associated with bariatric surgery utilization in Maryland

Multivariable logistic regression revealed significant associations between neighborhood socioeconomic status, demographic characteristics, insurance type, comorbidities, and bariatric surgery utilization in Maryland between 2018 and 2020 (Table 3).

Compared to individuals from prosperous neighborhoods, the odds of undergoing bariatric surgery were significantly lower for those in mid-tier (OR = 0.743, 95% CI: 0.698–0.792) and distressed neighborhoods (OR = 0.697, 95% CI: 0.639–0.760). A similar trend was seen for individuals in comfortable (OR = 0.893, 95% CI: 0.842–0.946) and at-risk neighborhoods (OR = 0.893, 95% CI: 0.832–0.959).

Age was inversely associated with surgery utilization. Patients aged 45–64 years had significantly lower odds of receiving bariatric surgery compared to those aged 18–44 (OR = 0.463, 95% CI: 0.441–0.486), and those aged ≥65 years had dramatically lower odds (OR =

0.142, 95% CI: 0.128–0.158). Females were more than twice as likely as males to undergo bariatric surgery (OR = 2.620, 95% CI: 2.482–2.765).

In terms of race and ethnicity, Black individuals had significantly higher odds of surgery compared to Whites (OR = 1.297, 95% CI: 1.238–1.359), as did Hispanic individuals (OR = 1.114, 95% CI: 1.005–1.235). No significant differences were observed among individuals categorized as "Other."

Insurance type was strongly associated with utilization. Compared to self-pay patients, those with private insurance had the highest odds of surgery (OR = 8.611, 95% CI: 6.077–12.200), followed by those with other insurance (OR = 3.160), Medicaid (OR = 2.783), and Medicare (OR = 1.726) (all $p < 0.01$).

Patients with Obesity Class III were more than twice as likely to receive surgery compared to those with Class II obesity (OR = 2.252, 95% CI: 2.145–2.365).

Comorbidity burden was also associated: patients with a CCI of 1–2 had increased odds (OR = 1.528, 95% CI: 1.444–1.616), while CCI >2 was not significantly associated with utilization.

Finally, urbanicity revealed geographic disparities. Compared to patients in rural areas, those in urban (OR = 0.687) and suburban (OR = 0.741) areas were significantly less likely to undergo surgery, while no significant difference was seen for residents of small towns (Table 3).

Sensitivity Analysis Using the Area Deprivation Index

As a sensitivity analysis, the Area Deprivation Index (ADI) was used in place of the Distressed Communities Index to assess neighborhood socioeconomic status (Table 4). Individuals from

moderately deprived neighborhoods (25th–75th percentile) had 18% lower odds of undergoing bariatric surgery compared to those from the least deprived areas (OR = 0.821, 95% CI: 0.778–0.865, $p < 0.001$), while those from the most deprived neighborhoods (>75th percentile) had 21% lower odds (OR = 0.790, 95% CI: 0.747–0.835, $p < 0.001$). These findings confirm a consistent socioeconomic gradient in bariatric surgery utilization, reinforcing the robustness of the primary results (Table 4).

Race as a Moderator of the Association between Neighborhood Distress and Bariatric Surgery Utilization.

The association between neighborhood socioeconomic status—measured using the Distressed Communities Index (DCI)—and bariatric surgery utilization showed variation by race. Across all DCI quintiles, Black patients were more likely than White patients to undergo bariatric surgery. The marginal effect of being Black versus White increased with community distress, from 0.2% (95% CI: –0.4%, 0.9%) in the most prosperous neighborhoods to 1.8% (95% CI: 1.2%, 2.3%) in the most distressed communities. In the middle three quintiles (Comfortable, Mid-Tier, and At-Risk), the marginal effects ranged from 1.0% to 1.3%, all statistically significant except in the most prosperous areas. (Figure 1). For individuals categorized as 'Other' race/ethnicity, race did not appear to moderate the association between bariatric surgery utilization and the Distressed Communities Index, suggesting no significant variation in utilization across DCI quintiles within this subgroup (Table 4).

DISCUSSION

This study yielded three important findings. First, despite meeting eligibility criteria, only 6.5% of individuals underwent bariatric surgery higher than the national average of 1% but still markedly low, highlighting a substantial gap between clinical eligibility and treatment uptake. Second, there was a clear socioeconomic gradient in bariatric surgery utilization. Individuals residing in socioeconomically distressed neighborhoods, as measured by the Distressed Communities Index (DCI), were significantly less likely to undergo surgery compared to those in more affluent areas. Surgery rates were highest among individuals in prosperous communities and declined progressively across increasing levels of neighborhood disadvantage. Third, race and ethnicity moderate the association between neighborhood socioeconomic status and bariatric surgery utilization. Black individuals had significantly higher utilization than White individuals across all DCI quintiles, with the largest difference observed in the most distressed neighborhoods. In contrast, Hispanic individuals only had significantly higher utilization than Whites when residing in the most distressed neighborhoods. For other racial and ethnic groups, race did not significantly modify the relationship between neighborhood distress and surgery utilization.

These findings highlight a complex interaction between race, place, and access to bariatric surgery. The observed decline in utilization among residents of more distressed communities aligns with previous literature indicating that lower neighborhood socioeconomic status (nSES) is associated with reduced access to elective surgical care[45,56,115,116]. Contributing factors may include limited healthcare infrastructure, fewer specialty providers, transportation challenges, and lower health literacy in underserved communities[115,117,118]. Despite Maryland's All-Payer

Model which minimizes variation in hospital reimbursement rates and aims to reduce healthcare disparities these structural barriers persist and continue to shape access to surgical obesity care[119,120].

The higher odds of bariatric surgery among Black individuals across all levels of neighborhood distress contrasts with national patterns that typically show lower utilization among Black patients[19,121,122]. This divergence may reflect a combination of increased clinical need, greater provider awareness of obesity disparities, and public health or hospital-level efforts to promote equitable access[123]. In addition, obesity is more prevalent and often more severe among Black individuals, potentially leading to higher referral rates[124,125]. The consistent pattern across all DCI quintiles, with a notable intensification in distressed areas, indicates that targeted equity-promoting strategies may be working more effectively in these settings. In contrast, Hispanic patients only experienced greater utilization in the most distressed neighborhoods, indicating persistent disparities in more socioeconomically advantaged areas[126]. Cultural and linguistic barriers, immigration-related concerns, and differences in healthcare-seeking behavior may contribute to these patterns and warrant targeted intervention[127-130].

Together, these results underscore the importance of intersectional approaches to understanding disparities in bariatric surgery. While race and neighborhood disadvantage independently affect access to care, their interaction reveals deeper structural inequities that influence treatment uptake[131-133]. Tailored strategies are needed to expand access in high-poverty neighborhoods and to ensure that underrepresented racial and ethnic groups are not overlooked in referral and treatment pathways[134]. Future research should explore the mechanisms underlying these patterns, including qualitative assessments of patient experience and provider decision-making. By

addressing both community- and individual-level barriers, public health systems can move toward more equitable delivery of bariatric surgery.

Study Limitations

This study has important strengths. The use of the Distressed Communities Index, a multidimensional and validated measure of neighborhood socioeconomic status, offers a comprehensive assessment of community-level deprivation and its impact on bariatric surgery utilization. Conducted in Maryland, a state operating under the All-Payer Model, the study benefits from a unique policy environment that reduces variability in hospital reimbursement rates and minimizes financial barriers. This setting allows for a more focused analysis of non-financial determinants of healthcare access. In addition, the use of a large, population-based dataset that captures a racially and ethnically diverse cohort enhances the internal validity and generalizability of the findings within the state of Maryland.

However, this study also has important limitations. The use of administrative inpatient data restricts the analysis to available clinical and demographic variables, limiting the ability to account for individual-level factors such as health beliefs, cultural perceptions, patient preferences, and implicit provider biases that may influence surgery uptake. The dataset also lacks information on outpatient referral patterns, and insurance precertification processes which could further contextualize the observed disparities. In addition, because the study design is cross-sectional, causal inferences regarding the relationship between nSES, race/ethnicity, and bariatric surgery utilization should be made cautiously.

Future research should prioritize longitudinal designs to examine how changes in neighborhood conditions and healthcare policies influence bariatric surgery access over time. Qualitative studies could further enrich understanding by capturing patient and provider perspectives on barriers and facilitators to surgery. Efforts to expand access should focus on addressing structural barriers in socioeconomically distressed communities, such as limited healthcare infrastructure and transportation challenges. Culturally tailored public health initiatives particularly those targeting Hispanic populations may help bridge communication gaps and enhance informed decision-making. Provider training and standardized referral protocols may also help ensure equitable access across racial and ethnic groups.

Conclusion:

This study highlights the substantial influence of neighborhood socioeconomic status on bariatric surgery utilization in Maryland, with individuals residing in the most distressed communities significantly less likely to undergo surgery compared to those in more affluent areas. Despite this overall socioeconomic gradient, the moderating role of race and ethnicity reveals important nuances: Black individuals had consistently higher utilization rates than White individuals across all DCI quintiles, with the greatest difference observed in the most distressed neighborhoods. In contrast, Hispanic individuals only exhibited higher utilization in the most socioeconomically disadvantaged areas, while no significant differences were observed among other racial or ethnic groups. These findings suggest that while some progress has been made in reducing racial disparities, particularly for Black patients, structural barriers related to socioeconomic context continue to limit access especially for Hispanics and those living in distressed neighborhoods. To promote equity in bariatric surgery access, policymakers and healthcare systems must adopt

targeted, intersectional strategies that account for both community-level disadvantages and racial and ethnic disparities.

TABLES

Table 1: Baseline Characteristics of Bariatric Surgery–Eligible Individuals by Distressed Communities Index Quintile in Maryland

	Total Population (N=154,665)	Prosperous (n=33,382)	Comfortable (n=41,729)	Mid-Tier (n=33,934)	At-Risk (n=20,690)	Distressed (n=24,930)	Chi-Square	p-value
Age (mean + std)	56.2 15.9	58.1 15.8	57.0 15.8	55.5. 16.1	55.3 15.8	54.4 15.2	35.768	<0.001
Age (Yr.)							1.10E+03	<0.001
18-44Yr.	33,002 (22.6%)	6,191 (19.7%)	8,315 (21.1%)	7,288 (23.4%)	4,758 (24.4%)	6,450 (26.6%)		
45/64Yr.	62,158 (42.6%)	12,708 (40.4%)	16,647 (42.2%)	13,496 (43.3%)	8,385 (43.0%)	10,922 (45.0%)		
>64Yr.	50,626 (34.7%)	12,582 (40.0%)	14,444 (36.7%)	10,361 (33.3%)	6,337 (32.5%)	6,902 (28.4%)		
Female	95,146 (65.3%)	19,433 (61.7%)	25,292 (64.2%)	20,651 (66.3%)	12,914 (66.3%)	16,856 (69.5%)	405.039	<0.001
Race/Ethnicity							1.10E+04	<0.001
White	82,962 (53.6%)	23,263 (69.7%)	24,932 (59.8%)	15,101 (44.5%)	10,825 (52.3%)	8,841 (35.5%)		
Black	62,824 (40.6%)	8,218 (24.6%)	14,474 (34.7%)	16,044 (47.3%)	8,655 (41.8%)	15,433 (61.9%)		
Hispanic	5,832 (3.8%)	1,074 (3.2%)	1,428 (3.4%)	2,124 (6.3%)	855 (4.1%)	351 (1.4%)		
Other	3,047 (2.0%)	827 (2.5%)	895 (2.1%)	665 (2.0%)	355 (1.7%)	305 (1.2%)		
Insurance							5.60E+03	<0.001
Self-Pay	1,678 (1.1%)	263 (0.8%)	420 (1.0%)	533 (1.6%)	259 (1.3%)	203 (0.8%)		
Medicare	67,327 (43.6%)	14,691 (44.1%)	18,290 (43.9%)	14,030 (41.4%)	9,060 (43.8%)	11,256 (45.2%)		
Medicaid	31,053 (20.1%)	3,935 (11.8%)	6,735 (16.2%)	7,512 (22.2%)	4,989 (24.1%)	7,882 (31.7%)		
Private	51,525 (33.4%)	13,754 (41.2%)	15,392 (36.9%)	11,157 (32.9%)	6,031 (29.2%)	5,191 (20.9%)		
Other	2,921 (1.9%)	708 (2.1%)	833 (2.0%)	677 (2.0%)	335 (1.6%)	368 (1.5%)		
CCI							180.755	<0.001
CCI =0	25,417 (16.4%)	5,528 (16.6%)	6,890 (16.5%)	6,033 (17.8%)	3,409 (16.5%)	3,557 (14.3%)		
CCI= 1-2	32,848 (21.2%)	7,333 (22.0%)	8,956 (21.5%)	7,189 (21.2%)	4,292 (20.7%)	5,078 (20.4%)		

CCI >2	96,400 (62.3%)	20,521 (61.5%)	25,883 (62.0%)	20,712 (61.0%)	12,989 (62.8%)	16,295 (65.4%)		
Obesity Classification							446.972	<0.001
Class I Obesity	62,283 (40.3%)	14,627 (43.8%)	17,214 (41.3%)	13,610 (40.1%)	7,961 (38.5%)	8,871 (35.6%)		
Class II Obesity	92,382 (59.7%)	18,755 (56.2%)	24,515 (58.8%)	20,324 (59.9%)	12,729 (61.5%)	16,059 (64.4%)		
Urban							6.00E+04	<0.001
Rural	12,817 (8.3%)	4,073 (12.2%)	3,595 (8.6%)	2,788 (8.2%)	1,990 (9.6%)	371 (1.5%)		
Small Town	10,554 (6.8%)	1,416 (4.2%)	3,113 (7.5%)	1,643 (4.8%)	451 (2.2%)	3,931 (15.8%)		
Suburban	102,561 (66.3%)	25,965 (77.8%)	33,423 (80.1%)	25,463 (75.0%)	13,988 (67.6%)	3,722 (14.9%)		
Urban	28,733 (18.6%)	1,928 (5.8%)	1,598 (3.8%)	4,040 (11.9%)	4,261 (20.6%)	16,906 (67.8%)		

Table 2: Baseline Characteristics of Bariatric Surgery Eligible Individuals by Utilization Status

Bariatric Surgery Utilization	Total Population	Bariatric surgery Utilizers	Non-Utilizers	Chi-Square	P-value
	(N=154,665)	(N=10,784)	(n=143,881)		
Age (Yr.)	56.2 ± 15.9	44.1 ± 11.6	57.2 ± 15.8	t=84.348	<0.001
Age (Yr.)				6.80E+03	<0.001
18-44Yr.	37,264 (24.1%)	5,656 (52.5%)	31,608 (22.0%)		
445-64Yr.	65,177 (42.1%)	4,638 (43.0%)	60,539 (42.1%)		
≥65Yr.	52,224 (33.8%)	490 (4.5%)	51,734 (36.0%)		
Distressed Communities Index				158.387	<0.001
Prosperous	33,382 (21.6%)	2,645 (24.5%)	30,737 (21.4%)		
Comfortable	41,729 (27.0%)	3,085 (28.6%)	38,644 (26.9%)		
Mid-Tier	33,934 (21.9%)	2,204 (20.4%)	31,730 (22.1%)		
At-Risk	20,690 (13.4%)	1,487 (13.8%)	19,203 (13.4%)		
Distressed	24,930 (16.1%)	1,363 (12.6%)	23,567 (16.4%)		
Race/Ethnicity				364.235	<0.001
White	82,962 (53.6%)	4,834 (44.8%)	78,128 (54.3%)		
Black	62,824 (40.6%)	5,209 (48.3%)	57,615 (40.0%)		
Hispanic	5,832 (3.8%)	503 (4.7%)	5,329 (3.7%)		
Other	3,047 (2.0%)	238 (2.2%)	2,809 (2.0%)		
Insurance				7.90E+03	
Self-Pay	1,678 (1.1%)	33 (0.3%)	1,645 (1.1%)		
Medicare	67,327 (43.6%)	975 (9.0%)	66,352 (46.2%)		
Medicaid	31,053 (20.1%)	2,087 (19.4%)	28,966 (20.2%)		<0.001
Private	51,525 (33.4%)	7,549 (70.1%)	43,976 (30.6%)		
Other	2,921 (1.9%)	138 (1.3%)	2,783 (1.9%)		
Charlson Comorbidity Index				3.4E+03	
CCI 0	25,417 (16.4%)	3,240 (30.0%)	22,177 (15.4%)		
Index (1,2)	32,848 (21.2%)	3,631 (33.7%)	29,217 (20.3%)		
Index >2	96,400 (62.3%)	3,913 (36.3%)	92,487 (64.3%)		<0.001
Sex				1.6E+03	
Male	53,534 (34.6%)	1,812 (16.8%)	51,722 (36.0%)		
Female	101,122 (65.4%)	8,972 (83.2%)	92,150 (64.1%)		

Obesity Class				1.70E +03	<0.001
Class II	62,283 (40.3%)	2,344 (21.7%)	59,939 (41.7%)		
Class III	92,382 (59.7%)	8,440 (78.3%)	83,942 (58.3%)		
Urban				34.72 5	<0.001
Rural	12,817 (8.3%)	971 (9.0%)	11,846 (8.2%)		
Small Town	10,554 (6.8%)	744 (6.9%)	9,810 (6.8%)		
Suburban	102,561 (66.3%)	7,281 (67.5%)	95,280 (66.2%)		
Urban	28,733 (18.6%)	1,788 (16.6%)	26,945 (18.7%)		

Table 3: Factors associated with Bariatric Surgery Utilization in Maryland (2018-2020)

Bariatric Surgery Utilization	Odds Ratio	Std. Err.	z	P>z	95% CI	
Distressed Communities Index						
Prosperous	Reference					
Comfortable	0.893	0.026	-3.840	<0.001	0.842	0.946
Mid-Tier	0.743	0.024	-9.180	<0.001	0.698	0.792
At-Risk	0.893	0.033	-3.100	0.002	0.832	0.959
Distressed	0.697	0.031	-8.160	<0.001	0.639	0.760
Age (Yr.)						
18-44Yr.	Reference					
45/64Yr.	0.463	0.012	-30.820	<0.001	0.441	0.486
>64Yr.	0.142	0.008	-35.300	<0.001	0.128	0.158
Female (ref. Male)	2.620	0.072	34.890	<0.001	2.482	2.765
Race and Ethnicity						
White	Reference					
Black	1.297	0.031	10.930	<0.001	1.238	1.359
Hispanic	1.114	0.059	2.060	0.040	1.005	1.235
Other	1.003	0.073	0.040	0.971	0.869	1.158
Insurance						
Self-Pay	Reference					
Medicare	1.726	0.313	3.010	0.003	1.210	2.463
Medicaid	2.783	0.497	5.730	<0.001	1.961	3.951
Private	8.611	1.531	12.110	<0.001	6.077	12.200
Other	3.160	0.627	5.800	<0.001	2.142	4.661
Charlson Comorbidity Index						
CCI 0	Reference					
Index (1,2)	1.528	0.044	14.790	<0.001	1.444	1.616
Index >2	1.013	0.031	0.430	0.664	0.955	1.075
Obesity Class III (ref.class II)	2.252	0.056	32.610	<0.001	2.145	2.365
Urbanicity						
Rural	Reference					
Small Town	1.003	0.055	0.060	0.951	0.901	1.118
Suburban	0.741	0.029	-7.730	<0.001	0.687	0.800
Urban	0.687	0.035	-7.460	<0.001	0.622	0.758
_cons	0.011	0.002	-24.380	<0.001	0.008	0.016

FIGURE

Figure 1: Marginal effects of race on bariatric surgery utilization by neighborhood distress (DCI), Maryland 2018–2020

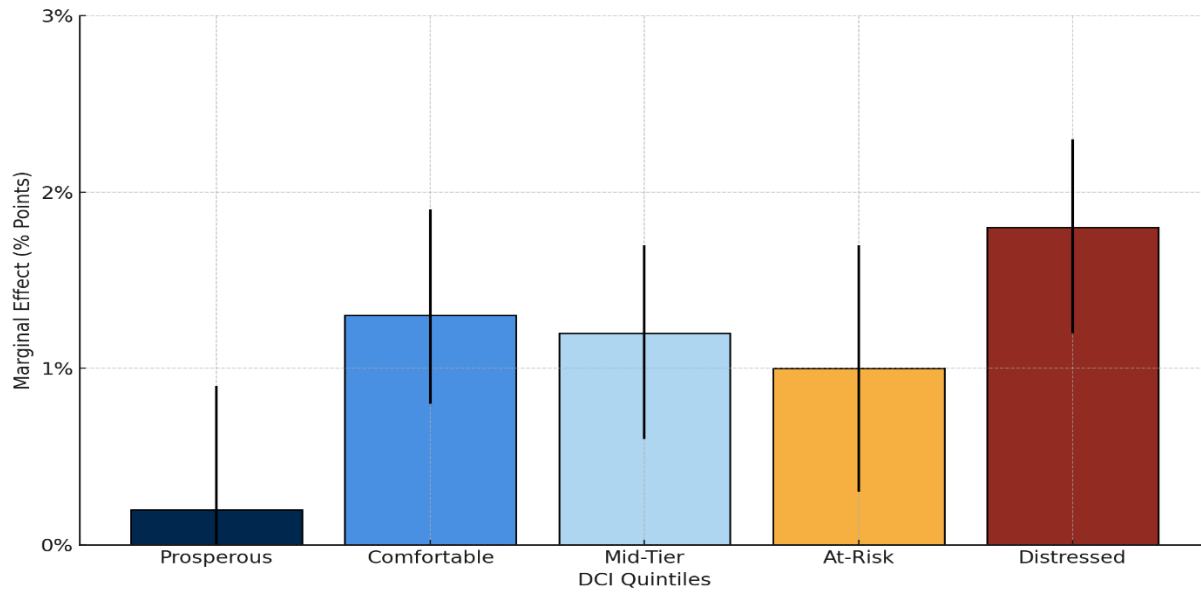

Table 4: Marginal Effects of Race & Ethnicity (Hispanic, Other vs. White) on Bariatric Surgery Utilization by DCI, Maryland 2018–2020

Hispanic vs. White	**Distressed Communities Index**	Marginal Effects	95% CI		P-value
	Prosperous	0.4%	-1.0%	1.8%	0.57
	Comfortable	0.9%	-0.3%	2.0%	0.13
	Mid-Tier	0.3%	-0.6%	1.2%	0.53
	At-Risk	0.5%	-1.0%	2.1%	0.51
	Distressed	3.3%	-0.6%	6.0%	0.56
Other vs. White	**Distressed Communities Index**				
	Prosperous	0.4%	-1.1%	2.0%	0.58
	Comfortable	0.6%	-0.8%	2.1%	0.39
	Mid-Tier	-0.5%	-2.1%	1.1%	0.55
	At-Risk	-0.3%	-2.5%	1.9%	0.79
	Distressed	-1.0%	-3.1%	1.2%	0.38

Marginal effects (with 95% confidence intervals) of race and ethnicity (Hispanic vs. White and Other vs. White) on the likelihood of bariatric surgery utilization, stratified by neighborhood socioeconomic status (DCI quintiles). Estimates represent the percentage point difference in the predicted probability of undergoing bariatric surgery for Hispanic and Other race/ethnicity groups compared to White individuals within each DCI category. Positive values indicate higher likelihood of utilization compared to White individuals; negative values indicate lower likelihood.

Chapter 3: PAPER 2-Short-Term Post-Operative Complication

The Impact of Neighborhood Socioeconomic Status on Short-Term Postoperative Complications Following Bariatric Surgery

Abstract

Background: Obesity is a significant public health concern, affecting over 41.9% of adults in the United States and contributing to increased risk of chronic conditions and premature mortality. Bariatric surgery is the most effective long-term intervention for severe obesity, offering sustained weight loss and improved metabolic outcomes. However, socioeconomic disparities persist in both the utilization and postoperative outcomes of bariatric surgery, particularly among those who live in socioeconomically disadvantaged neighborhoods.

Objective: This study evaluates the impact of neighborhood socioeconomic status (nSES), as measured by the Distressed Communities Index (DCI), on short-term postoperative complications following bariatric surgery. Additionally, we investigate whether race/ethnicity moderates this association.

Methods: We conducted a retrospective cohort study using data from the Maryland State Inpatient Database (SID) from 2018 to 2020. The study population included adult patients (≥18 years) who underwent bariatric surgery during the study period. The primary outcome was the occurrence of short-term postoperative complications (e.g. gastrointestinal leaks, gastrointestinal bleeding and venous thromboembolism) categorized using a composite complication variable defined as no complications or one or more complication. The primary independent variable was nSES, classified into five categories based on the DCI (prosperous, comfortable, mid-tier, at-risk, and distressed). Multivariable ordinal logistic regression models were used to assess the

association between nSES and the occurrence of one or more complication post-surgery, adjusting for demographic, clinical, and socioeconomic and geographic covariates. We tested whether race/ethnicity modified the association between nSES and the selected outcomes.

Results: Among 10,784 patients who underwent bariatric surgery in the study period, 94.7% had no postoperative complications, 5.3% experienced one or more complications. The most common complications were venous thromboembolism (2.2%) and gastrointestinal leaks (0.9%). Multivariable analyses revealed no statistically significant association between nSES and the occurrence of short-term postoperative complications. Additionally, race/ethnicity did not significantly moderate this relationship.

Conclusions: This study found no significant association between neighborhood socioeconomic disadvantages and the occurrence of short-term postoperative complications following bariatric surgery.

INTRODUCTION

Obesity is a significant public health challenge in the United States, affecting approximately 41.9%[135] of adults and contributing to increased risk of chronic conditions such as diabetes, cardiovascular disease, and certain cancers and premature mortality[72,136]. The economic burden of obesity continues to rise, with estimates exceeding $347.5 billion annually[137]. Bariatric surgery has emerged as the most effective long-term intervention for severe obesity (BMI ≥ 40 kg/m² or BMI ≥ 35 kg/m² with comorbidities), offering sustained weight loss, improved metabolic outcomes, and reduced mortality[138,139]. Over the past two decades, bariatric surgery has evolved with improved techniques and safety profiles, leading to a steady increase in its utilization[140-142]. In 2017 alone, approximately 228,000 bariatric procedures were performed in the United States[141]. Advances in surgical protocols, anesthesia, and post-operative care have significantly reduced complication rates, making bariatric surgery safer and more accessible[143]. However, despite these advancements, socioeconomic disparities in utilization and outcomes persist.

Although bariatric surgery offers significant benefits, short-term post-operative complications remain a concern[144,145]. Common complications include gastrointestinal (GI) leaks, surgical site infections (SSIs), and venous thromboembolism (VTE), all of which can lead to increased morbidity, prolonged hospital stays, readmissions, and reduced patient satisfaction[146,147]. These complications may discourage eligible patients from pursuing surgery due to concerns about post-operative recovery and financial costs[148]. Patients from disadvantaged communities may be particularly at risk for these adverse outcomes due to systemic barriers to high-quality post-operative care, a higher prevalence of pre-existing comorbid conditions, and other social determinants of health that may impact post-surgical recovery[25,49].Understanding the factors that

contribute to these disparities is essential to improving surgical outcomes and increasing equitable access to bariatric surgery.

Several studies have underscored the clinical and public health implications of post-operative complications following bariatric surgery[144,149-151]. For instance, gastrointestinal leaks, though relatively rare, can occur in up to 5% of patients and are associated with significant morbidity and mortality[152]. Surgical site infections affect approximately 0.4% to 12% of patients, depending on the procedure type and hospital protocols[153]. Venous thromboembolism (VTE) remains a leading cause of post-operative morbidity despite prophylaxis, with reported incidence rates ranging from 0.2% to 1.3%[154]. Importantly, the risk of these complications may be amplified in patients from low socioeconomic status (SES) neighborhoods, where limited healthcare resources, lower health literacy, reduced social support, and under-resourced post-acute care settings can hinder timely recognition and management of early signs of complications[49,155]. These neighborhood-level structural barriers can compound individual vulnerabilities, increasing the likelihood of adverse outcomes and potentially reinforcing long-standing disparities in surgical recovery and overall health status[155,156].

Social determinants of health (SDOH), including individual-level socioeconomic status (SES), race, insurance type, and income, play a critical role in post-surgical outcomes[157]. Studies have shown that individuals with lower SES or public insurance experience higher rates of complications, prolonged hospital stays, and readmissions following bariatric surgery[157]. These disparities are often attributed to variations in access to high-quality healthcare, lower rates of post-operative follow-up, and differential exposure to environmental and lifestyle risk factors[49,158]. While much research has focused on individual-level socioeconomic factors, there is

growing recognition that neighborhood socioeconomic status (nSES) may offer additional predictive value in understanding socioeconomic disparities in surgical outcomes[118,159].

Neighborhood socioeconomic status captures broader structural and environmental factors that influence health beyond individual-level SES[160-162]. Lower nSES neighborhoods are characterized by higher poverty rates, lower education levels, reduced access to healthcare services, food insecurity, and higher levels of chronic stress[163,164]. These factors contribute to disparities in post-operative complications and hospital readmissions among bariatric surgery patients[49,165]. Research suggests that individuals from socioeconomically distressed neighborhoods face greater barriers to healthcare access, which may translate to delayed diagnosis and treatment of complications, poorer adherence to post-operative care, and worse overall outcomes[49,163]. However, there is limited research on how nSES, as measured by indices such as the Distressed Communities Index (DCI), influences short-term post-operative complications following bariatric surgery.

Race and ethnicity are established factors that influence health outcomes, and their interaction with neighborhood socioeconomic status may further exacerbate the observed disparities[121,122]. Black and Hispanic patients undergoing bariatric surgery have been found to experience higher rates of complications compared to White patients, even after adjusting for individual SES[25,122]. Structural inequities in healthcare delivery, differential referral patterns, and provider biases contribute to these disparities[100,122]. Given that racial and ethnic minority populations are more likely to reside in low-nSES neighborhoods, it is crucial to investigate whether race/ethnicity moderates the association between nSES and short-term post-operative complications[100,166]. This study aims to address this gap by examining whether nSES, as measured by the DCI, is associated with short-term post-operative complications after bariatric surgery, including

gastrointestinal leaks, surgical site infections, and venous thromboembolism (VTE). This study will also examine whether race/ethnicity moderates this association. Understanding these relationships is essential to improving healthcare equity and optimizing bariatric surgery outcomes for patients from disadvantaged communities.

METHODOLOGY

Study Design and Population

This study employs a retrospective cohort design using data from the Maryland State Inpatient Database (SID) from 2018 to 2020[167]. The study population includes all adult patients (≥18 years) who underwent bariatric surgery in Maryland during the study period. Bariatric procedures were identified using ICD-10 procedure codes for sleeve gastrectomy, gastric bypass, adjustable gastric banding, and other recognized bariatric surgeries. The Maryland SID provides a comprehensive, statewide dataset that captures hospital discharges across all payers, ensuring reduced bias related to insurance status.

Primary Outcome: Short-Term Post-Operative Complications

The primary outcome of interest was the occurrence of one or more short-term post-operative complications following bariatric surgery. This outcome was defined as a binary variable: individuals who did not experience any short-term complication were coded as 0, while those who experienced at least one complication were coded as 1. To construct this variable, we included the most commonly reported short-term post-operative complications in the literature.

The selected complications included gastrointestinal leaks, stenosis, gastrointestinal bleeding, venous thromboembolism (VTE), gastroesophageal reflux disease (GERD), pouch stress, persistent vomiting, post-operative pain, acute cholecystitis, and in-hospital mortality. These

complications were chosen based on their documented prevalence and clinical relevance as early adverse outcomes among bariatric surgery patients[168-171].

In addition to this binary composite measure, we also examined the association between neighborhood socioeconomic status (as measured by the Distressed Communities Index, DCI) and individual short-term complications, specifically, gastrointestinal leaks, venous thromboembolism (VTE), and gastrointestinal leaks.

Main Explanatory Variable: Neighborhood Socioeconomic Status (nSES)

The main independent variable is nSES, captured using the DCI quintiles. The DCI is a ZIP-code-based measure developed by the Economic Innovation Group, integrating seven economic indicators (e.g., unemployment rates, poverty levels, housing vacancy rates, and business vitality) to assess socioeconomic distress. For this study, the DCI is categorized into five quintiles: Quintile 1 (Prosperous), Quintile 2 (Comfortable), Quintile 3 (Mid-tier), Quintile 4 (At-risk), Quintile 5 (Distressed)

Higher quintiles represent greater socioeconomic disadvantages, allowing for a dose-response analysis of nSES and postoperative complications.

Covariates

To account for potential confounding, the study will adjust for key demographic, clinical, socioeconomic and geographic factors, including:

Demographic Variables: Age (continuous), sex (male/female), race/ethnicity (White, Black, Hispanic, and Other).

Clinical Variables: Charlson commodity index (CCI) is a weighted scoring system that quantifies the burden of comorbid conditions based on their severity and association with mortality, with higher scores indicating greater comorbidity burden and risk of adverse health outcomes) and obesity severity (BMI $\geq$35 kg/m^2 with comorbidities or BMI $\geq$40 kg/m^2)[172-176].

Socioeconomic Factors: Insurance type (Medicare, Medicaid, Private, Self-pay), and household median income (categorized into quintiles based on census data).

Geographical Factors:

The Urban/Suburban/Small Town/Rural designation variable (Urban) categorizes patients based on their residential area type. This numeric categorical variable ranges from 1 to 4, representing the following classifications: Rural (1), Small Town (2), Suburban (3), and Urban (4). This variable was included in the analysis to examine potential geographic disparities in bariatric surgery utilization based on urbanicity and rurality.

Statistical Analysis

Descriptive analyses were conducted to summarize baseline characteristics by the occurrence of short-term post-operative complications or otherwise. Categorical variables were compared using χ^2 tests, while continuous variables were assessed using either t-tests or Mann-Whitney U tests, as appropriate.

To evaluate the association between nSES and the occurrence of short-term post-operative complications, multivariable logistic regression models were employed. The binary outcome variable indicated whether a patient experienced any short-term complication (1) or none (0) following bariatric surgery. The primary explanatory variable was the DCI, used as a measure of

nSES. Covariates were included in a stepwise fashion across models to assess the robustness of the association. The logistic regression model was specified as follows:

$$Logit(P(Y=1))=\alpha+\beta1(DCI)+\beta2(Covariates)$$

Given well-documented racial and ethnic disparities in surgical outcomes, race/ethnicity was tested as a potential effect modifier in the association between DCI and post-operative complications. An interaction term between DCI and race/ethnicity was included in a separate model to assess whether the relationship varied across racial groups:

$$Logit(P(Y=1))=\alpha+\beta1(DCI)+\beta2(Covariates)+\beta3(Race)+\beta13(Race\times DCI)$$

The interaction term (β_{13}) captured whether the effect of DCI on the likelihood of experiencing a post-operative complication differed by race/ethnicity. A statistically significant interaction ($p < 0.05$) was interpreted as evidence of effect modification.

Sensitivity Analyses

To ensure the robustness of the results, sensitivity analyses were conducted using alternative approaches to measure neighborhood socioeconomic status (nSES) and address potential confounding. The Area Deprivation Index (ADI) was used as an alternative measure of nSES to assess whether the findings were consistent across different socioeconomic indices.

Ethical Considerations

This study utilizes de-identified secondary data from the Maryland SID, exempt from direct patient consent under HIPAA regulations. The study protocol was reviewed and approved by the University of Maryland Institutional Review Board (2284677-1).

RESULT

Table 1 presents the demographic, socioeconomic, and clinical characteristics of the study population, stratified by the occurrence of any short-term post-operative complication following bariatric surgery. Among the 10,784 individuals included in the analysis, 566 (5.3%) experienced at least one short-term complication, while 10,218 (94.8%) did not.

The mean age of the overall cohort was 44.1 ± 11.6 years. Patients who experienced complications were significantly older (49.1 ± 12.3 years) compared to those without complications (43.8 ± 11.5 years; $p < 0.001$). Age group distribution also differed significantly ($p < 0.001$), with the highest complication rate among patients aged 45–64 years (51.2%), followed by those 18–44 years (36.4%) and those ≥65 years (12.4%).

Women comprised 83.2% of the total sample, with a slightly lower representation among those with complications (79.9%) compared to those without (83.4%; $p = 0.029$). While the racial and ethnic distribution did not reach statistical significance ($p = 0.165$), White patients had a slightly higher proportion in the complication group (49.1%) compared to those without complications (44.6%). Black patients made up 48.3% of the total cohort, followed by Hispanic (4.7%) and Other race (2.2%).

Insurance type was significantly associated with complication status ($p < 0.001$). Patients with Medicare were more likely to experience complications (21.2%) than those without (8.4%), while those with private insurance were less likely to experience complications (62.9%) compared to their counterparts without complications (70.4%).

Comorbidity burden, as measured by the Charlson Comorbidity Index (CCI), was significantly associated with complications ($p < 0.001$). Nearly half of the patients with complications (48.4%) had a CCI >2, compared to 35.6% among those without complications. Patients with no comorbidities (CCI = 0) were less likely to experience complications (21.2% vs. 30.5%).

Obesity classification was also associated with complication risk ($p = 0.028$). Class I obesity was more common among patients with complications (25.4%) compared to those without (21.5%). Class II obesity was slightly less prevalent among those with complications (74.6%) compared to the non-complication group (78.5%).

There were no statistically significant differences in complication status by neighborhood socioeconomic status (DCI quintiles; $p = 0.664$) or urban-rural residence ($p = 0.109$), though minor variations were observed across geographic categories.

Table 2: Incidence of Short-Term Postoperative Complications Following Bariatric Surgery

Table 2 presents the incidence of short-term postoperative complications among patients who underwent bariatric surgery.

Among the 10,784 individuals who underwent bariatric surgery, 566 (5.3%) experienced at least one short-term postoperative complication (Table 2). The most common complication was venous thromboembolism, occurring in 2.2% of patients. Gastrointestinal leak and gastrointestinal bleeding were also notable, with rates of 0.9% and 0.6%, respectively. These findings highlight the relatively low but clinically significant risk of adverse events following bariatric surgery.

Table 3: Adjusted Odds of Postoperative Complications Following Bariatric Surgery

After adjusting for relevant covariates, there were no statistically significant differences in the odds of experiencing any postoperative complication across DCI quintiles when compared to patients from Prosperous communities (Table3). Patients from Distressed communities had a lower, though non-significant, odds of developing any complication (aOR: 0.81; 95% CI: 0.56–1.17), while those from Comfortable (aOR: 0.96; 95% CI: 0.76–1.21), Mid-Tier (aOR: 1.01; 95% CI: 0.78–1.30), and At-Risk (aOR: 0.93; 95% CI: 0.69–1.25) communities showed similar non-significant associations (Table 3).

With regard to specific complications, no DCI quintile demonstrated significantly higher or lower adjusted odds of gastrointestinal (GI) leaks, venous thromboembolism (VTE), or GI bleeding compared to Prosperous communities. Individuals from Distressed areas had lower odds of GI leaks (aOR: 0.60; 95% CI: 0.21–1.71) and GI bleeding (aOR: 0.73; 95% CI: 0.23–2.29), though these results were not statistically significant. Interestingly, patients from At-Risk communities had a lower odds of VTE (aOR: 0.63; 95% CI: 0.39–1.03), which approached statistical significance (Table 3).

Regarding race and ethnicity, adjusted odds of overall complications did not significantly differ between Black (aOR: 0.99; 95% CI: 0.81–1.20), Hispanic (aOR: 1.18; 95% CI: 0.77–1.81), or Other race (aOR: 0.75; 95% CI: 0.38–1.48) individuals when compared to White patients. However, Hispanic patients had significantly higher adjusted odds of experiencing GI leaks (aOR: 2.31; 95% CI: 1.09–4.90), suggesting a potential disparity in this subgroup. No other statistically significant differences were observed in the rates of specific complications by race or ethnicity (Table 3).

Table 4: Marginal Effects of Race on Postoperative Complications across Community Distress Levels

The marginal effects analysis assessed whether race (Black vs. White) moderated the relationship between neighborhood distress and postoperative complications following bariatric surgery. Across all DCI quintiles, the estimated differences in complication rates between Black and White patients were small and statistically non-significant, with confidence intervals crossing zero (Table 4).

For overall postoperative complications, the marginal differences ranged from -0.8% in Comfortable communities (95% CI: -2.4% to 0.9%) to 0.9% in Mid-Tier communities (95% CI: -1.1% to 3.0%), indicating no meaningful racial disparities by neighborhood socioeconomic status. Similar patterns were observed for individual complications. For gastrointestinal (GI) leaks, the largest observed difference was 0.4% in Prosperous and Mid-Tier communities, with all estimates falling within non-significant ranges (Table 4).

Venous thromboembolism rates showed a marginal increase of 0.6% for Black patients in both At-Risk and Distressed communities, though these differences were also not statistically significant. Likewise, GI bleeding exhibited negligible differences, with marginal effects close to zero across all quintiles.

Overall, the results suggest that race does not significantly moderate the relationship between community distress levels and short-term complications following bariatric surgery (Table 4).

Table 5: Marginal Effects of Hispanic and Other Race on Postoperative Complications

Marginal effects analysis was conducted to evaluate whether Hispanic and Other race/ethnicity moderated the association between neighborhood distress and composite postoperative

complications following bariatric surgery. Across all DCI quintiles, there were no statistically significant differences in complication rates between Hispanic and White patients (Table 5). The marginal effect estimates ranged from -1.6% in Distressed communities (95% CI: -8.4% to 5.2%) to 2.1% in Comfortable communities (95% CI: -2.7% to 6.9%), with all confidence intervals crossing zero (Table 5).

For individuals categorized as Other race, results were similarly non-significant in most quintiles, except in Prosperous communities, where Other race patients had significantly lower odds of complications compared to White patients (marginal effect: -4.2%, 95% CI: -6.9% to -1.5%). In all other DCI quintiles, the marginal effects for other race ranged from -0.6% to 5.0%, with wide confidence intervals that included zero, indicating no meaningful differences. The interaction analyses for Hispanic and Other race groups were limited by small sample sizes, particularly in the distressed quintile, which may have reduced statistical power to detect differences (Table 5).

DISCUSSION

In this study, we found that only 5.3% of individuals undergoing bariatric surgery had a post-operative complication. We did not observe a significant association between nSES, as measured by the DCI, and the risk of experiencing short-term postoperative complications following bariatric surgery. This finding persisted regardless of whether short-term post-operative complications was analyzed as a composite measure aggregating all short-term postoperative outcomes or as individual complications such as gastrointestinal leaks, venous thromboembolism, and gastrointestinal leaks. We were also unable to identify any moderating effect of race/ethnicity on the association between neighborhood socioeconomic status and short-

term postoperative complications, as the relationship remained consistent across racial and ethnic groups, with no significant differences observed.

The distribution of short-term post-operative complications following bariatric surgery revealed that the vast majority of patients (94.7%) experienced no complications, while 5.3% had one or more complications. Among specific complications, gastrointestinal leaks occurred in 0.9% of patients, venous thromboembolism in 2.2%, and gastrointestinal bleeding in 0.6%. In-hospital mortality was rare, occurring in only 0.2% of cases.

These findings highlight that while bariatric surgery is generally associated with low complication rates, certain post-operative risks remain, particularly venous thromboembolism and gastrointestinal leaks, which may warrant closer monitoring[154,177]. The low incidence of in-hospital mortality aligns with prior research indicating the safety of bariatric procedures in well-selected patients[178,179]. However, the presence of even a small percentage of severe complications underscores the importance of timely post-operative surveillance and management, particularly among patients with higher baseline risk factors[165,180].

The lack of statistical significance suggests that the socioeconomic characteristics of the neighborhoods where patients reside may not be a strong determinant of early postoperative complications after bariatric surgery. One potential explanation for this null finding is the relatively low proportion of patients who experienced these complications, which may have resulted in an underpowered analysis. Given that short-term postoperative complications are uncommon following bariatric surgery, our study may have lacked the statistical sensitivity to detect subtle associations. Additionally, it is possible that nSES is not directly related to the immediate post-surgical period in the same way it influences long-term health outcomes. Patients undergoing bariatric surgery often receive standardized perioperative care protocols that may

mitigate disparities in short-term complications. Furthermore, hospital-level factors, such as adherence to enhanced recovery after surgery (ERAS) protocols and institutional quality measures, may play a larger role in determining short-term outcomes than neighborhood socioeconomic conditions. These factors could collectively attenuate the expected association between nSES and early post-surgical complications. This finding suggests that the overall safety of bariatric surgery in the short term may, in part, be influenced by standardized perioperative protocols and advancements in surgical techniques. However, further research is needed to determine whether these factors fully explain the low incidence of complications across diverse patient populations.

Beyond statistical power limitations, several mechanisms may contribute to the lack of association between nSES and postoperative complications. Maryland's unique All-Payer Model, which standardizes hospital reimbursement rates across all patient populations, likely plays a significant role in reducing healthcare disparities[181]. This payment model ensures more equitable access to high-quality bariatric surgery and perioperative care, thereby minimizing variations in outcomes based on neighborhood socioeconomic status[182]. In addition, the existence of high-volume bariatric surgery centers in Maryland, which adhere to standardized perioperative protocols, may have further mitigated disparities in early postoperative complications[183]. Many of these centers implement enhanced recovery after surgery (ERAS) pathways, which include preoperative risk stratification, perioperative infection control measures, and thromboembolism prophylaxis[184]. Such standardization in care delivery likely reduces the influence of socioeconomic factors on immediate postoperative outcomes.

Another plausible explanation for the non-significant associations observed in our study is selection bias. Patients residing in lower socioeconomic status (SES) neighborhoods who

successfully undergo bariatric surgery may represent a more resilient and health-conscious subset of their communities. These individuals may have better access to healthcare resources, stronger social support, or higher health literacy compared to others in similarly disadvantaged neighborhoods, potentially attenuating the expected association between neighborhood SES and post-operative complications[49]. These individuals may have greater health literacy, better engagement in preoperative optimization programs, and stronger social support systems, all of which could mitigate the negative effects of neighborhood deprivation on surgical outcomes[49,185]. This phenomenon, often referred to as the "healthy surgical candidate" effect, suggests that the most disadvantaged patients, who might be at the highest risk for poor outcomes, may not be included in the study due to barriers in accessing surgery in the first place[186]. Consequently, the observed cohort may not fully capture the range of disparities that exist in the broader population.

It is also important to consider whether the DCI and ADI indices, while widely used measures of neighborhood socioeconomic status, may not fully capture the specific social determinants of health such as social support, housing stability, or access to culturally competent care that may have more of a direct influence on postoperative outcomes[32,187]. For example, individual-level SDOHs such as patient education, access to transportation, health literacy, or adherence to postoperative care plans may better reflect the specific challenges that influence surgical recovery and continuity of care[117]. It is possible that such unmeasured factors play a more critical role in shaping short-term surgical outcomes than the broader neighborhood characteristics captured by the DCI and ADI[188,189]. DCI and ADI do not capture these challenges because these indices primarily assess structural deprivation based on economic and community-level indicators. Future research should explore whether integrating social vulnerability indices that

encompass a broader range of health-related socioeconomic risks may yield more nuanced insights into the relationship between nSES and postoperative outcomes.

Policy Implications

The findings of this study have important implications for healthcare policy and bariatric surgery research. The absence of disparities in short-term postoperative complications suggests that Maryland's standardized reimbursement policies and hospital quality improvement initiatives may be effectively ensuring equitable perioperative care. This highlights the potential for health policy interventions to mitigate socioeconomic disparities in surgical outcomes, particularly in states that adopt similar models of healthcare delivery. However, while short-term complications did not vary by nSES, previous research suggests that long-term surgical outcomes, including weight loss maintenance, postoperative readmissions, and nutritional deficiencies, may be more vulnerable to socioeconomic disparities[155]. Future studies should investigate whether neighborhood deprivation influences long-term surgical success, postoperative follow-up adherence, and late complications following bariatric surgery.

Study Limitations

Several limitations should be considered when interpreting our findings. The reliance on administrative data from the Maryland State Inpatient Database introduces potential misclassification bias, as postoperative complications were identified using ICD-10 codes rather than clinical validation. Additionally, administrative databases lack information on post-discharge factors, such as adherence to follow-up visits, engagement in dietary counseling, and access to postoperative support services, all of which could influence long-term outcomes. Another limitation is the low event rate of postoperative complications, which may have limited

the statistical power to detect subtle associations between nSES and outcomes. Future studies could enhance statistical power by pooling data across multiple states or using multi-institutional registries to increase sample sizes. Additionally, the observational study design prevents us from inferring causality, as the relationship between nSES and postoperative outcomes may be confounded by unmeasured hospital- and provider-level factors. Finally, the generalizability of our findings is limited to Maryland, given that the state's unique healthcare financing model may not be representative of other regions with different reimbursement structures.

To build on these findings, future research should investigate long-term postoperative outcomes by socioeconomic status to determine whether disparities emerge over time. Further studies should also explore the role of patient engagement, social support, and healthcare navigation in postoperative recovery, incorporating qualitative methods and patient-reported outcomes to provide a more comprehensive understanding of the barriers faced by disadvantaged patients. Additionally, research should integrate more granular socioeconomic measures, including employment status, food security, and health literacy, to better capture the complex interplay between social determinants and surgical outcomes. Expanding this analysis to other types of surgical procedures may also provide broader insights into the role of neighborhood factors in shaping health outcomes beyond bariatric surgery.

Conclusion

In conclusion, this study adds to the growing body of literature examining the relationship between neighborhood socioeconomic status and surgical outcomes. Our findings suggest that in Maryland, where healthcare delivery is highly regulated and standardized, nSES does not significantly impact short-term postoperative complications following bariatric surgery. This underscores the potential protective role of equitable healthcare policies and standardized

perioperative protocols in reducing disparities in surgical outcomes. While these results are reassuring, they also raise important questions about long-term disparities, patient-level socioeconomic barriers, and the adequacy of existing indices in capturing healthcare-related social risk factors. Addressing these gaps through future research and targeted policy interventions will be essential to ensuring that bariatric surgery remains accessible, effective, and equitable for all patients, regardless of socioeconomic background.

TABLES

Table 1. Baseline Characteristics of Bariatric Surgery Patients in Maryland by Postoperative Complication Status, 2018–2020

Variable	Total Population (N=10,784)	Complication (n=566)	None (n=10,218)	Chi Squared	p-value
Distressed Communities Index				2.395	0.664
Prosperous	2,645 (24.5%)	149 (26.3%)	2,496 (24.4%)		
Comfortable	3,085 (28.6%)	164 (29.0%)	2,921 (28.6%)		
Mid-Tier	2,204 (20.4%)	117 (20.7%)	2,087 (20.4%)		
At-Risk	1,487 (13.8%)	74 (13.1%)	1,413 (13.8%)		
Distressed	1,363 (12.6%)	62 (11.0%)	1,301 (12.7%)		
Age (mean + std)	44.1 + 11.6	49.1 + 12.3	43.8 + 11.5	t=-10.650	<0.001
Age (Yr.)				119.224	<0.001
18-44Yr.	5,656 (52.5%)	206 (36.4%)	5,450 (53.3%)		
45/64Yr.	4,638 (43.0%)	290 (51.2%)	4,348 (42.6%)		
>64Yr.	490 (4.5%)	70 (12.4%)	420 (4.1%)		
Female (ref. Man)	8,972 (83.2%)	452 (79.9%)	8,520 (83.4%)	4.763	0.029
Race/Ethnicity				5.096	0.165
White	4,834 (44.8%)	278 (49.1%)	4,556 (44.6%)		
Black	5,209 (48.3%)	253 (44.7%)	4,956 (48.5%)		
Hispanic	503 (4.7%)	26 (4.6%)	477 (4.7%)		
Other	238 (2.2%)	9 (1.6%)	229 (2.2%)		
Insurance				113.751	<0.001
Self-Pay	33 (0.3%)	4 (0.7%)	29 (0.3%)		
Medicare	975 (9.0%)	120 (21.2%)	855 (8.4%)		
Medicaid	2,087 (19.4%)	80 (14.1%)	2,007 (19.7%)		
Private	7,549 (70.0%)	356 (62.9%)	7,193 (70.4%)		
Other	138 (1.3%)	6 (1.1%)	132 (1.3%)		
CCI				41.660	<0.001
CCI =0	3,240 (30.0%)	120 (21.2%)	3,120 (30.5%)		
CCI= 1-2	3,631 (33.7%)	172 (30.3%)	3,459 (33.9%)		
CCI >2	3,913 (36.3%)	274 (48.4%)	3,639 (35.6%)		
Obesity Classification				4.822	0.028
Class I Obesity	2,344 (21.7%)	144 (25.4%)	2,200 (21.5%)		
Class II Obesity	8,440 (78.3%)	422 (74.6%)	8,018 (78.5%)		
Urban				6.064	0.109
Rural	971 (9.0%)	65 (11.5%)	906 (8.9%)		
Small Town	744 (6.9%)	44 (7.8%)	700 (6.9%)		

Suburban	7,281 (67.5%)	373 (65.9%)	6,908 (67.6%)		
Urban	1,788 (16.6%)	84 (14.8%)	1,704 (16.7%)		

Table 2: Short-Term Complication Rates Post-Bariatric Surgery

Complications (n=566)	Frequency	Percentages (%)
All Complications	566	5.30%
Commonest Complications		
Venous Thromboembolism	238	2.20%
Gastrointestinal Leak	94	0.90%
Gastrointestinal Bleeding	62	0.60%

Table 3: Adjusted Odds of Post-op Complications following Bariatric Surgery by DCI Quintiles and Race & Ethnicity, Maryland 2018–2020

Complications	All Complications	GIT Leaks	Venous Thromboembolism	GIT Bleeding
Distressed Communities Index				
Prosperous	Reference	Reference	Reference	Reference
Comfortable	0.96 (0.76-1.21)	0.85 (0.50-1.47)	0.86 (0.60-1.21)	1.12 (0.56-2.26)
Mid-Tier	1.01 (0.78-1.30)	0.95 (0.52-1.72)	0.96 (0.66-1.40)	0.84 (0.37-1.94)
At-Risk	0.93 (0.69-1.25)	1.02 (0.53-1.98)	0.63 (0.39-1.03)	1.67 (0.77-3.63)
Distressed	0.81 (0.56-1.17)	0.60 (0.21-1.71)	0.75 (0.44-1.29)	0.73 (0.23-2.29)
Race & Ethnicity				
White	Reference	Reference	Reference	Reference
Black	0.99 (0.81-1.20)	1.05 (0.66-1.67)	1.03 (0.76-1.38)	1.49 (0.84-2.66)
Hispanic	1.18 (0.77-1.81)	2.31 (1.09-4.90)	0.95 (0.45-1.98)	1.56 (0.45-5.34)
Other	0.75 (0.38-1.48)	-	1.06 (0.43-2.65)	0.95 (0.12-7.11)

Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) for postoperative complications following bariatric surgery, stratified by neighborhood socioeconomic status (DCI quintiles) and race/ethnicity. All models are adjusted for age, sex, insurance type, Charlson Comorbidity Index, and obesity class. The "Prosperous" DCI quintile and "White" race group serve as reference categories. "–" indicates insufficient data for model estimation.

Table 4: Marginal Effects of Race (Black vs. White) on Post-Op Complications following Bariatric Surgery by DCI, Maryland 2018–2020

	All Complications	GIT Leaks	Venous Thromboembolism	GIT Bleeding
Distressed Communities Index				
Prosperous	0.2% (-1.7% to 2.1%)	0.4% (-0.5 to 1.3%)	0% (-1.4% to 1.3%)	0.3% (-0.4% to 1.0%)
Comfortable	-0.8% (-2.4% to 0.9%)	-0.4% (-1.1% to 0.2%)	-0.1% (-1.2% to 1.0%)	0.2% (-0.4% to 0.8%)
Mid-Tier	0.9% (-1.1% to 3.0%)	0.4% (-0.4% to 1.2%)	-0.3% (-1.8% to 1.1%)	0% (-0.6% to 0.6%)
At-Risk	0.1% (-2.3% to 2.4%)	0.3% (-0.8% to 1.3%)	0.6% (-0.7% to 2.0%)	0.4% (-0.7% to 1.5%)
Distressed	-0.6% (-3.2% to 2.1%)	-0.6% (-1.8% to 0.7%)	0.6% (-1.0% to2.2%)	0.2% (-0.6% to1.0%)

Marginal effects (with 95% confidence intervals) of race (Black vs. White) on the likelihood of postoperative complications following bariatric surgery, stratified by neighborhood socioeconomic status (DCI quintiles). Estimates represent the percentage point difference in predicted probability of complications for Black patients compared to White patients within each DCI category. Positive values indicate higher probability among Black patients; negative values indicate lower probability.

Table 5: Marginal Effects of Race (Hispanic, Other vs. White) on Post-Op Complications following Bariatric Surgery by DCI, Maryland 2018–2020

		All Complications
Hispanic vs. White	**Distressed Communities Index**	
	Prosperous	1.1% (-4.0% to 6.3%)
	Comfortable	2.1% (-2.7% to 6.9%)
	Mid-Tier	-0.1% (-4.2% to 4.0%)
	At-Risk	1.9% (-4.8% to8.5%)
	Distressed	-1.6% (-8.4% to 5.2%)
Other vs. White	**Distressed Communities Index**	
	Prosperous	-4.2% (-6.9% to -1.5%)
	Comfortable	-0.4% (-5.4% to 4.6%)
	Mid-Tier	0.9% (-7.1% to 9.0%)
	At-Risk	-0.6% (-9.1% to 7.9%)
	Distressed	5.0% (-13.1% to 23.1%)

Marginal effects (with 95% confidence intervals) of race (Black vs. White) on the likelihood of experiencing any postoperative complication following bariatric surgery, stratified by neighborhood socioeconomic status (DCI quintiles). Estimates represent the percentage point difference in the predicted probability of complications for Black patients compared to White patients within each DCI category. Positive values indicate a higher probability among Black patients, and negative values indicate a lower probability. Marginal effects for individual complications were not reported due to limited sample size.

Chapter 4: PAPER 3- Healthcare Quality Measures

Neighborhood Socioeconomic Status and Healthcare Quality Measures Following Bariatric Surgery in Maryland

ABSTRACT

Introduction: Bariatric surgery is the most effective treatment for severe obesity, yet significant socioeconomic disparities in access and outcomes persist, especially in disadvantaged communities. Neighborhood socioeconomic status (nSES) influences healthcare utilization, complication rates, and recovery, but its impact within state-specific reimbursement models remains understudied.

Objective: This study examines whether nSES, measured by the Distressed Communities Index (DCI), is independently associated with prolonged hospital stays and higher readmission rates after bariatric surgery. It also evaluates the interaction between race/ethnicity and nSES, to assess disparities in post-surgical outcomes.

Methodology: A retrospective cohort study was conducted using Maryland State Inpatient Databases (SID) from 2018 to 2020. The study population included all adult patients who underwent bariatric surgery, identified using ICD-10 procedure codes. The primary explanatory variable was nSES, operationalized using DCI quintiles, linked to patient ZIP codes. The primary outcomes were hospital length of stay (continuous variable) and readmission (binary variable: Yes/No). Multivariate linear regression (for hospital stay) and logistic regression (for readmission) were performed, adjusting for demographic factors (age, sex, race/ethnicity), clinical characteristics (preexisting comorbidities using the Charlson Comorbidity Index (CCI) and, obesity class), and socioeconomic indicators (insurance type) and Geographic classification.

Interaction terms were included to evaluate whether race/ethnicity modified the association between nSES and these outcomes.

Result: Among 10,784 bariatric surgery recipients, the majority were Black (48.3%), female (83.1%), with a mean age of 44.1 ± 11.6 years. Length of stay did not differ significantly by DCI Quintiles; patients in distressed areas had similar odds of prolonged hospitalization compared to those in prosperous areas ($\beta = 0.045$; 95% CI: –0.111 to 0.201; $p = 0.575$). Readmission risk was higher in distressed neighborhoods (OR = 1.64; 95% CI: 0.76–3.54; $p = 0.207$), though not statistically significant. No interaction was observed between nSES and race/ethnicity.

Conclusion: Residents of disadvantaged neighborhoods showed a non-significant trend toward higher readmission without increased hospital stay. Findings underscore the need to enhance post-discharge care for socioeconomically vulnerable populations.

INTRODUCTION

Healthcare Quality Measures Following Bariatric Surgery

Bariatric surgery is the most effective long-term intervention for severe obesity, leading to sustained weight loss and improvement in obesity-related comorbidities such as diabetes and hypertension[144,190,191]. However, post-operative healthcare quality measures, including hospital length of stay (LOS) and readmission rates, serve as critical indicators of patient outcomes and healthcare system efficiency and post-surgical recovery[192,193]. Prolonged hospital stays increase healthcare costs and indicate potential complications, while readmissions often reflect suboptimal perioperative care, surgical complications, or social barriers to recovery[194,195]. Readmissions can result from surgical complications, inadequate post-operative care, or socioeconomic barriers that affect follow-up adherence and recovery. Understanding factors influencing these healthcare quality measures is essential for optimizing surgical outcomes and reducing disparities in post-bariatric surgery care.

Length of hospital stay and readmission rates are particularly important metrics in bariatric surgery due to their implications for patient safety, recovery, and healthcare resource utilization[196-198]. Prolonged hospital stay following bariatric surgery is often indicative of post-operative complications such as bleeding, infection, or delayed gastrointestinal function, and is associated with increased healthcare costs and poorer patient satisfaction[196,199]. However, some extended stays may be preventable with enhanced recovery protocols, multidisciplinary care teams, and improved perioperative monitoring[200]. Similarly, readmissions reported in 5–15% of bariatric cases can result from surgical site infections, anastomotic leaks, dehydration, nutritional deficiencies, and poorly managed comorbidities[196,201,202]. Many of these readmissions may be

mitigated through better discharge planning, early post-discharge follow-up, patient education, and robust outpatient support systems[202].

Social Determinants of Health and Healthcare Quality Measures

Social determinants of health (SDOH) play a pivotal role in shaping healthcare quality measures. Individual-level socioeconomic factors such as income, education, insurance status, and healthcare access influence patients' ability to receive preoperative care, adhere to post-operative instructions, and manage surgical complications[203-205]. Lower-income patients are more likely to experience delayed follow-ups, higher rates of post-surgical complications, and increased readmissions due to barriers in healthcare access, nutrition, and medication adherence[205,206]. In addition, racial and ethnic disparities persist, with Black and Hispanic patients experiencing poorer surgical outcomes compared to White patients, likely due to differences in healthcare access, systemic barriers, and comorbid conditions and neighborhood socioeconomic context[207,208].

Neighborhood Socioeconomic Status and Surgical Outcomes

Beyond individual-level factors, neighborhood socioeconomic status (nSES) is an independent determinant of health outcomes[209,210]. Neighborhood socioeconomic characteristics may include income distribution, employment rates, housing stability, and healthcare accessibility[211,212]. Studies have shown that patients from low-nSES neighborhoods have longer hospital stays and higher readmission rates following various surgical procedures, including cardiac, orthopedic, and oncologic surgeries[37,213,214]. These disparities may be driven by higher baseline comorbidities, limited healthcare resources, and increased psychosocial stressors in socioeconomically disadvantaged neighborhoods[215,216]. Despite growing recognition of the

impact of nSES on surgical outcomes, research on its influence in bariatric surgery patients within state-specific healthcare models remains limited.

Measuring Neighborhood Socioeconomic Status: Comparative Metrics

Several composite indices have been developed to quantify neighborhood disadvantage, each incorporating different socioeconomic factors. The Area Deprivation Index (ADI) is a census tract-based measure[56] that ranks neighborhood deprivation by considering education, income, employment, and housing quality[54]. The Social Vulnerability Index (SVI), developed by the CDC, evaluates community vulnerability to external stressors by incorporating socioeconomic status, household composition, minority status, and housing characteristics[54]. In contrast, the Distressed Communities Index (DCI) is a ZIP-code-based measure developed by the Economic Innovation Group, which provides a broader economic assessment of neighborhood distress by incorporating factors such as unemployment rates, poverty levels, business decline, and housing conditions[51,217]. While each of these indices offers valuable insights, the DCI captures a more comprehensive picture of economic resilience and structural barriers within communities, making it particularly useful for evaluating healthcare disparities and outcomes[56,58]. The DCI is particularly advantageous for assessing the impact of nSES on healthcare outcomes, providing a more comprehensive and dynamic reflection of economic advantages compared to ADI and SVI[56,97].

Intersection of Race/Ethnicity, nSES, and Healthcare Quality Measures

The intersection of race/ethnicity and neighborhood disadvantage may further exacerbate disparities in post-operative outcomes[218,219]. Minority patients, particularly Black and Hispanic individuals living in low-nSES neighborhoods, might be at increased risk for prolonged hospital

stays and higher readmissions due to the compounded effects of systemic barriers, lower healthcare access, and implicit biases in clinical decision-making[132,155,220]. This intersectionality highlights the need to examine racial/ethnic disparities within the broader context of neighborhood socioeconomic disadvantages to fully understand disparities in bariatric surgery outcomes.

This study aims to evaluate the independent association between nSES (measured using the DCI) and healthcare quality measures (hospital length of stay and readmissions) following bariatric surgery in Maryland. In addition, it seeks to assess the moderating role of race/ethnicity in the relationship between nSES and post-operative outcomes. Given Maryland's unique All-Payer Model, which standardizes hospital payment rates across all payers, this study provides a distinct opportunity to investigate healthcare disparities in a regulated reimbursement environment.

Methodology

Study Design and Population

This study employs a retrospective cohort design using data from the Maryland State Inpatient Database (SID) from 2018 to 2020[221]. The study population includes all adult patients (≥18 years) who underwent bariatric surgery, identified using ICD-10 procedure codes for sleeve gastrectomy, gastric bypass, and other bariatric procedures. Maryland SID provides a comprehensive, statewide dataset capturing hospital discharges across all payers under the Maryland All-Payer Model, ensuring reduced bias related to insurance status.

Primary Outcomes

The primary outcomes for this study include hospital length of stay (LOS) and readmission rates. Hospital LOS is measured as a continuous variable, representing the number of inpatient days

following bariatric surgery. The second outcome, readmission, is defined as a binary variable (Yes/No), indicating whether a patient was readmitted within 30 days of discharge.

Main Explanatory Variable: Distressed Communities Index (DCI)

Neighborhood socioeconomic status (nSES) was assessed using the DCI, a ZIP-code-based measure developed by the Economic Innovation Group. The DCI integrates various economic indicators, including unemployment rates, poverty levels, housing vacancy rates, and business decline, to provide a comprehensive assessment of economic distress at the community level. For this study, DCI was categorized into quintiles, allowing for a gradient analysis of economic disadvantages. The first quintile represents the least distressed communities, while the fifth quintile represents the most distressed neighborhoods.

Covariates

Several demographics, clinical, socioeconomic, and geographic covariates were included in the analysis to account for potential confounders. Demographic variables included age, sex, and race/ethnicity, with racial/ethnic groups categorized as White, Black, Hispanic, and Other. Clinical factors such as hypertension, diabetes was measured using the Charlson commodity index[173,222], and obesity class (based on BMI categories) were incorporated to account for underlying comorbidities that may influence post-operative outcomes. Socioeconomic factors included primary insurance type, categorized as Medicare, Medicaid, Private, or Uninsured while Geographic context was stratified as Rural, Small Town, Suburban and Urban.

Statistical Analysis

All statistical analyses were conducted using Stata 17 utilizing complete case analysis to account for missing data. Descriptive statistics were used to summarize patient characteristics, with

means and standard deviations (SD) reported for continuous variables and proportions calculated for categorical variables. Chi-square tests and t-tests were used to compare baseline characteristics across DCI quintiles.

To assess the association between nSES and healthcare quality metrics, multivariable regression models were employed. For hospital length of stay, a linear regression model was used, adjusting for demographic, clinical, socioeconomic, and geographic covariates. The model was specified as follows:

$$LOSi=\beta 0+\beta 1(DCI)+\beta 2(Covariates)$$

For readmission rates, a logistic regression model was applied, with results reported as adjusted odds ratios (OR) with 95% confidence intervals (CI):

$$Logit\ (P(Y=1)) =\alpha+\beta\ 1(DCI) +\beta\ 2(Covariates)$$

Where: OLS for hospital stay (continuous) and a binary logistic regression for readmissions indicating whether a patient experienced a readmission following surgery (1 = Yes, 0 = No).

DCI: Main explanatory variable; α: Intercept term.;

Interaction terms were included to evaluate whether the relationship between nSES and post-surgical outcomes was modified by race/ethnicity:

$$Logit(P(Y=1))=\alpha+\beta 1(DCI)+\beta 2(Covariates\ )+\beta 3(Race)+\beta 13(Race\ X\ DCI\ )$$

Interaction Term (β13 (Race X DCI): This term captures how the effect of the DCI on the likelihood of the outcomes (hospital stay or readmission) following surgery changes depending on the individual's race/ethnicity. If significant, it indicates that the impact of DCI on these outcomes varies by racial group.

Sensitivity Analysis Using Alternative Socioeconomic Index

To validate the robustness of the findings, a sensitivity analysis was performed using the Area Deprivation Index (ADI), an alternative socioeconomic measure based on census tract data. Unlike the ZIP-code-based DCI, the ADI incorporates education, income, employment, and housing characteristics to assess neighborhood deprivation. By comparing models that used DCI versus ADI, this study evaluated whether ZIP-code-based socioeconomic distress (DCI) provided a more meaningful distinction in predicting bariatric surgery outcomes compared to a census-tract-based approach. This sensitivity analysis strengthened the study's conclusions regarding the impact of neighborhood disadvantage on healthcare quality metrics.

Ethical Considerations

This study utilized de-identified secondary data from the Maryland SID, which is exempt from direct patient consent under HIPAA regulations. The research protocol was reviewed and approved by the University of Maryland Institutional Review Board (2284677-1).

RESULTS

The study included 10,784 adults who underwent bariatric surgery in Maryland between 2018 and 2020, distributed across five DCI quintiles (Table 1). The mean age of the cohort was 44.1 ± 11.6 years, with significant variation by DCI Quintiles. Patients from prosperous neighborhoods were older on average (mean: 45.2 years), while those from distressed areas were younger (mean: 42.7 years). The proportion of younger adults (18–44 years) was highest in distressed neighborhoods (57.3%) and lowest in prosperous areas (48.0%). Conversely, older adults (≥65 years) were more prevalent in prosperous neighborhoods (5.5%) than in distressed ones (2.8%).

Women constituted 83.1% of the total population, with the highest proportions observed in at-risk (86.8%) and distressed (86.1%) communities. There were significant racial and ethnic differences by DCI quintile: White individuals represented the majority in prosperous neighborhoods (61.9%), while Black individuals were most prevalent in distressed areas (52.4%). Hispanic and other racial groups were more evenly distributed across the quintiles, although Hispanic patients had slightly higher representation in mid-tier and at-risk neighborhoods (Table 1).

Insurance coverage also demonstrated a clear socioeconomic gradient. Private insurance was more common in prosperous neighborhoods (78.6%) and decreased across quintiles, reaching 55.0% in distressed communities. Medicaid coverage followed the opposite trend, increasing from 11.3% in prosperous areas to 33.0% in distressed neighborhoods. Medicare coverage and self-pay rates remained relatively stable across groups.

The Charlson Comorbidity Index (CCI) showed that patients from distressed areas had the highest proportion with a CCI >2 (39.0%), indicating greater comorbidity burden. Obesity class also varied across quintiles: Class III obesity was more common in lower SES areas, increasing from 75.3% in prosperous to 82.9% in distressed neighborhoods (Table 1).

Geographic distribution differed significantly by SES. Patients from distressed communities were overwhelmingly urban (72.8%), while those from prosperous neighborhoods were more likely suburban (74.8%) or rural (13.0%). These findings highlight substantial demographic, clinical, and geographic disparities in bariatric surgery recipients across socioeconomic gradients, emphasizing the need for tailored public health and clinical interventions to address the distinct needs of disadvantaged populations (Table 1).

Unadjusted Comparison of Length of Stay and Readmissions by Neighborhood Socioeconomic Status

Unadjusted analyses showed no statistically significant differences in hospital length of stay or readmission rates across DCI quintiles among patients undergoing bariatric surgery (Table 2). The mean length of stay was consistent across quintiles, ranging from 1.82 ± 2.08 days in Distressed communities to 1.88 ± 2.00 days in At-Risk communities, with an overall mean of 1.85 ± 2.02 days. The F-test for comparison of means was non-significant ($p = 0.907$), indicating no variation in hospital stay duration by neighborhood socioeconomic status (Table 2).

Similarly, readmission rates did not differ significantly across DCI categories. Readmission rates ranged from 0.66% in Prosperous communities to 1.46% in Distressed communities, with an overall rate of 0.99%. A chi-square test yielded no statistically significant differences across groups ($\chi^2 = 6.885$, $p = 0.142$). These results suggest that, at the unadjusted level, neighborhood distress was not associated with differences in short-term postoperative outcomes (Table 2).

Unadjusted Comparison of Length of Stay and Readmissions by Race and Ethnicity

Unadjusted analyses revealed no statistically significant differences in hospital length of stay or readmission rates following bariatric surgery across racial and ethnic groups (Table 3). The mean length of stay was similar among White (1.88 ± 2.02 days), Black (1.86 ± 1.98 days), and Hispanic (1.83 ± 2.04 days) patients, with an overall average of 1.85 ± 2.01 days. An F-test comparing these means yielded a non-significant result ($p = 0.474$), indicating no evidence of variation by race/ethnicity (Table 3).

Readmission rates were also comparable across groups, with 0.84% of White, 1.01% of Black, and 1.03% of Hispanic patients readmitted within 30 days post-surgery. The overall readmission

rate was 0.99%. A chi-square test showed no significant difference in readmission rates between the groups ($\chi^2 = 0.752$, $p = 0.687$). These findings suggest that, in the unadjusted model, race and ethnicity were not associated with differences in short-term postoperative outcomes (Table 3).

Adjusted Association between Community Distress, Race, and Length of Stay

After adjusting for age, sex, insurance type, comorbidities, obesity classification, and urban categories, neighborhood socioeconomic status as measured by the DCI was not significantly associated with hospital length of stay following bariatric surgery (Table 4). Compared to individuals from Prosperous communities, those from Comfortable ($\beta = 0.011$; 95% CI: -0.091 to 0.113; $p = 0.833$), Mid-Tier ($\beta = 0.055$; 95% CI: -0.057 to 0.167; $p = 0.334$), At-Risk ($\beta = -0.017$; 95% CI: -0.142 to 0.109; $p = 0.792$), and Distressed ($\beta = -0.048$; 95% CI: -0.205 to 0.108; $p = 0.547$) communities had no statistically significant differences in length of hospital stay (Table 4).

Among racial and ethnic groups, Black patients had a significantly longer hospital stay compared to White patients ($\beta = 0.085$; 95% CI: 0.001 to 0.169; $p = 0.046$). No significant differences in length of stay were observed for Hispanic ($\beta = 0.036$; 95% CI: -0.145 to 0.218; $p = 0.695$) or Other race patients ($\beta = 0.119$; 95% CI: -0.134 to 0.372; $p = 0.357$). These findings suggest that, while community socioeconomic status was not independently associated with hospital stay duration, Black patients experienced modest but statistically significant increases in postoperative length of stay (Table 4).

Adjusted Association between Community Distress, Race, and Readmission

Multivariable logistic regression models adjusting for age, sex, insurance type, pre-existing comorbidity, obesity classification, and urbanicity revealed no statistically significant differences

in readmission rates across DCI quintiles or racial/ethnic groups (Table 5). Compared to individuals from Prosperous communities, those residing in Comfortable (aOR: 1.52; 95% CI: 0.84–2.75; p = 0.165), Mid-Tier (aOR: 1.74; 95% CI: 0.93–3.26; p = 0.084), At-Risk (aOR: 1.21; 95% CI: 0.58–2.52; p = 0.611), and Distressed (aOR: 1.41; 95% CI: 0.65–3.06; p = 0.386) communities did not have significantly elevated odds of readmission (Table 5).

Similarly, when stratified by race and ethnicity, no group showed a significant association with readmission compared to White patients. The adjusted odds ratios were 0.77 for Black patients (95% CI: 0.49–1.20; p = 0.249), 1.39 for Hispanic patients (95% CI: 0.58–3.35; p = 0.464), and 0.44 for individuals of Other races (95% CI: 0.06–3.23; p = 0.418). These findings suggest that neither neighborhood socioeconomic status nor race/ethnicity independently influenced 30-day hospital readmission risk following bariatric surgery (Table 5).

Marginal Effects of Race on Hospital Stay following Bariatric Surgery by DCI, Maryland 2018–2020

Marginal effects analysis was conducted to assess whether race moderated hospital length of stay following bariatric surgery across different levels of neighborhood socioeconomic distress (Table 6). Compared to White patients, Black patients had significantly longer hospital stays in Comfortable communities (marginal effect: +15.0%, 95% CI: 6.0% to 29.5%, p = 0.041). In other DCI quintiles, the differences in length of stay for Black patients were not statistically significant, with marginal effects ranging from -16.7% in Distressed areas to +12.4% in Mid-Tier communities, all with wide confidence intervals that crossed zero (Table 6).

Among Hispanic patients, none of the comparisons across DCI quintiles reached statistical significance. The marginal effects ranged from -7.8% in At-Risk communities to +25.1% in

Comfortable neighborhoods (95% CI: -8.9% to 59.1%, p = 0.148), indicating considerable variability but no consistent pattern of difference in hospital stay relative to White patients (Table 6).

For patients categorized as other race, a borderline significant increase in hospital stay was observed in Mid-Tier communities (marginal effect: +62.4%, 95% CI: -1.5% to 126.3%, p = 0.056). In all other DCI quintiles, marginal effects for other race were non-significant, with wide confidence intervals, including negative values, highlighting substantial uncertainty in the estimates (Table 6).

Marginal Effects of Race (Black vs. White) on Hospital Stay following Bariatric Surgery by DCI, Maryland 2018–2020

The marginal effects analysis evaluated whether race (Black vs. White) moderated the likelihood of hospital readmission following bariatric surgery across DCI quintiles (Table 7). Overall, the differences in readmission rates between Black and White patients were small and not statistically significant across all community distress levels. In Prosperous communities, the marginal difference was +0.3% (95% CI: -0.5% to 1.1%, p = 0.51), while in Comfortable communities, the estimate was -0.5% (95% CI: -1.3% to 0.4%, p = 0.26).

Patients from Mid-Tier and Distressed communities showed slightly lower readmission probabilities for Black patients compared to White patients (marginal effects: -0.9% and -0.4%, respectively), but confidence intervals again crossed zero, indicating non-significance. The At-Risk quintile showed no difference (0.0%; 95% CI: -0.9% to 1.0%, p = 0.92). These findings

suggest that race did not significantly influence readmission risk following bariatric surgery, regardless of neighborhood socioeconomic status (Table 7).

DISCUSSION

This study examined the relationship between neighborhood socioeconomic status (nSES) and key bariatric surgery outcomes, including readmission rates and hospital length of stay. Our initial hypothesis was that lower nSES would be associated with higher readmission rates and longer hospital stays due to systemic barriers affecting post-surgical recovery, such as reduced access to healthcare resources and support services. There was no statistically significant association between neighborhood socioeconomic status, as measured by the DCI, and either readmission rates or length of hospital stay following bariatric surgery after adjusting for relevant covariates. Sensitivity analyses using the ADI reinforced these findings, suggesting that neighborhood disadvantage alone may not be a primary driver of post-surgical outcomes. Instead, factors such as hospital quality, access to post-operative care, and systemic healthcare policies may mitigate the expected disparities[36,87,223,224].

The lack of a statistically significant association may be influenced by Maryland's All-Payer Model, which standardizes hospital reimbursement rates, potentially reducing financial barriers to care[119,120]. In addition, the presence of bariatric centers of excellence in the state may contribute to uniform surgical protocols and post-operative management, ensuring more equitable outcomes across socioeconomic groups[225-227]. While lower socioeconomic status has been linked to worse surgical outcomes in prior research[228,229], some studies consistent with ours have found that these associations weaken when hospital-level factors and policy-driven interventions are considered[228,230-232]. Future research should explore the role of individual-level

socioeconomic factors, healthcare literacy, and long-term adherence to post-surgical care in shaping bariatric surgery outcomes.

Race and ethnicity did not significantly modify the association between nSES and surgical outcomes, suggesting that broader structural determinants of health, such as access to care, provider networks, and community resources, may play a more influential role in post-surgical recovery than individual racial identity[233,234]. Standardized bariatric surgery protocols and post-operative care guidelines may also help mitigate disparities by ensuring consistent preoperative education, surgical management, and follow-up care[235,236]. However, unmeasured factors, such as implicit biases in healthcare delivery and differences in post-surgical adherence, may still contribute to disparities[237]. Addressing systemic barriers to care, including neighborhood healthcare infrastructure, insurance accessibility, and provider availability, may be more effective in reducing disparities than focusing solely on race or ethnicity.

Although our findings did not show significant associations, they underscore the complex interplay between socioeconomic status, healthcare policies, and surgical outcomes. Future research should investigate long-term weight loss maintenance, complication rates, and healthcare utilization patterns to better understand how social disadvantage manifests in bariatric surgery outcomes.

Policy and Research Implications

From a policy perspective, our findings suggest that neighborhood disadvantage alone may not be a sufficient predictor of post-surgical outcomes, particularly in healthcare systems implementing strong policy interventions such as Maryland's All-Payer Model. Nonetheless, the observed trends of higher readmission rates and prolonged hospital stays among patients from

distressed communities underscore the ongoing influence of socioeconomic disparities—though these may operate through more nuanced mechanisms. As the landscape of obesity treatment evolves with the growing availability of GLP-1 receptor agonists, such as semaglutide and tirzepatide, it is essential to contextualize the role of bariatric surgery within a broader treatment framework. While GLP-1s have demonstrated significant effectiveness in promoting weight loss and improving metabolic parameters, access remains limited by cost, insurance coverage, and long-term adherence challenges, particularly in underserved populations. Therefore, bariatric surgery should continue to be promoted as a viable and often necessary option for managing class II and III obesity, especially for patients who may not respond adequately to or cannot access pharmacologic therapies.

Future research should focus on integrating individual-level socioeconomic data with neighborhood-level indicators to better understand the pathways through which disadvantage affects surgical outcomes. Furthermore, targeted interventions to enhance post-surgical care adherence, improve patient education, and reduce barriers to follow-up—especially in underserved communities—are warranted. Nationally representative, longitudinal studies are needed to assess how emerging pharmacologic options and persistent socioeconomic disparities intersect to influence long-term outcomes in the management of severe obesity.

Study Limitations

This study has several limitations that should be acknowledged. First, while we utilized robust socioeconomic measures such as the DCI and ADI, these are neighborhood-level indicators and may not fully capture individual-level socioeconomic factors such as income, education, or healthcare access, which could independently influence hospital readmissions and length of stay. Second, our analysis was conducted within Maryland's All-Payer Model, a unique healthcare

system that may reduce socioeconomic disparities in access to care, potentially limiting the generalizability of our findings to other states with different healthcare reimbursement structures.

In addition, while our study suggests a trend toward higher readmissions and prolonged hospital stays in distressed communities, the lack of statistical significance may reflect insufficient power, residual confounding, or unmeasured variables, such as post-discharge care access and patient adherence to follow-up recommendations. Lastly, our reliance on administrative claims data introduces the potential for misclassification bias, as certain clinical and social factors influencing surgical outcomes (e.g., nutrition status, social support, and health literacy) are not captured in hospital discharge records. Future research should incorporate individual-level socioeconomic data, patient-reported outcomes, and qualitative assessments to better elucidate the mechanisms driving disparities in post-bariatric surgery outcomes.

Conclusion

In conclusion, our study found no statistically significant association between neighborhood socioeconomic status, as measured by the DCI, and either readmission rates or length of hospital stay following bariatric surgery. These findings suggest that neighborhood-level disadvantage, as captured by the DCI, may not independently predict these specific healthcare quality outcomes in a regulated healthcare environment such as Maryland's All-Payer Model. Nonetheless, neighborhood socioeconomic status remains a relevant contextual factor for understanding broader disparities in surgical care. Continued research is warranted to explore other structural and individual-level determinants that may contribute to variations in post-operative recovery and to inform targeted interventions for at-risk populations.

TABLES

Table 1. Baseline Characteristics of Bariatric Surgery Patients by Neighborhood Socioeconomic Status (DCI Quintiles) in Maryland, 2018–2020

	Total Population (N=10,784)	Prosperous (n=2,645)	Comfortable (n=3,085)	Mid-Tier (n=2,204)	At-Risk (n=1,487)	Distressed (n=1,363)	Chi-Square	p-value
Age (mean + std)	44.1 ±11.6	45.2 ±11.8	44.6 ±11.6	43.3 ±11.3	43.4 ±11.9	42.7 ±11 .4	16.19	<0.001
Age (Yr.)							72.2	<0.001
18-44Yr.	5,746 (52.2%)	1,317 (48.0%)	1,568 (49.8%)	1,219 (54.4%)	857 (56.8%)	785 (57.3%)		
45/64Yr.	4,766 (43.3%)	1,273 (46.4%)	1,415 (45.0%)	947 (42.2%)	583 (38.6%)	548 (40.0%)		
>64Yr.	501 (4.6%)	152 (5.5%)	165 (5.2%)	77 (3.4%)	69 (4.6%)	38 (2.8%)		
Female (ref. Man)	9,147 (83.1%)	2,140 (78.1%)	2,605 (82.8%)	1,912 (85.2%)	1,309 (86.8%)	1,181 (86.1%)	80.63	<0.001
Race/Ethnicity							805.165	<0.001
White	4,834 (44.8%)	1,638 (61.9%)	1,478 (47.9%)	767 (34.8%)	610 (41.0%)	11 (0.8%)		
Black	5,209 (48.3%)	812 (30.7%)	1,391 (45.1%)	1,243 (56.4%)	779 (52.4%)			
Hispanic	503 (4.7%)	111 (4.2%)	137 (4.4%)	157 (7.1%)	71 (4.8%)			
Other	238 (2.2%)	84 (3.2%)	79 (2.6%)	37 (1.7%)	27 (1.8%)			
Insurance							438.517	<0.001
Self-Pay	33 (0.3%)	9 (0.3%)	13 (0.4%)	3 (0.1%)	6 (0.4%)	2 (0.2%)		
Medicare	988 (9.0%)	217 (7.9%)	289 (9.2%)	189 (8.4%)	134 (8.9%)	159 (11.6%)		
Medicaid	2,110 (19.2%)	309 (11.3%)	481 (15.3%)	468 (20.9%)		453 (33.0%)		

					399 (26.5%)			
Private	7,737 (70.3%)	2,153 (78.6%)	2,324 (73.8%)	1,543 (68.8%)	963 (63.9%)	754 (55.0%)		
Other	143 (1.3%)	53 (1.9%)	41 (1.3%)	40 (1.8%)	6 (0.4%)	3 (0.2%)		
Charlson Comorbidity Index								
CCI =0	3,297 (29.9%)	769 (28.1%)	958 (30.4%)	704 (31.4%)	483 (32.0%)	383 (27.9%)		
CCI= 1-2	3,704 (33.6%)	916 (33.4%)	1,055 (33.5%)	781 (34.8%)	499 (33.1%)	453 (33.0%)		
CCI >2	4,012 (36.4%)	1,057 (38.6%)	1,135 (36.1%)	758 (33.8%)	527 (34.9%)	535 (39.0%)		
Obesity Classification								
Class I Obesity	2,401 (21.8%)	678 (24.7%)	754 (24.0%)	443 (19.8%)	292 (19.4%)	234 (17.1%)		
Class II Obesity	8,612 (78.2%)	2,064 (75.3%)	2,394 (76.1%)	1,800 (80.3%)	1,217 (80.7%)	1,137 (82.9%)	21.633	0.006
Urban								
Rural	1,016 (9.2%)	357 (13.0%)	261 (8.3%)	197 (8.8%)	169 (11.2%)	32 (2.3%)		
Small Town	775 (7.0%)	176 (6.4%)	270 (8.6%)	100 (4.5%)	22 (1.5%)	207 (15.1%)		
Suburban	7,426 (67.4%)	2,051 (74.8%)	2,518 (80.0%)	1,668 (74.4%)	1,055 (69.9%)	134 (9.8%)	51.17	<0.001

Urban	1,796 (16.3%)	158 (5.8%)	99 (3.1%)	278 (12.4%)	263 (17.4%)	998 (72.8%)		

Table 2: Adjusted Odds of 30-day Readmission by DCI Quintiles, Race & Ethnicity in Maryland

Distressed Communities Index	Total (N= 10,784)	Prosperous (n=2,742)	Comfortable (n=3,148)	Mid-Tier (n=2,243)	At-Risk (n=1,509)	Distressed (n=1,371)	Tests	P-value
Length of Hospital Stay	1.85 ± 2.02	1.84 ± 1.91	1.86 ± 2.03	1.87 ± 2.09	1.82 ± 2.08	1.88 ± 2.00	F-test: 0.25	0.907
Readmissions	107 (0.99%)	18 (0.66%)	33 (0.98%)	25 (1.11%)	13 (0.86%)	20 (1.46%)	chi2: 6.885	0.142

Model adjusted for age, sex, insurance type, pre-existing comorbidity, obesity classification and geographic classification.

Table 3: Length of Hospital Stay and Readmission Rates by Race and Ethnicity in Maryland

Race & Ethnicity	Total (N= 10,784)	White (n=3,204)	Black (n=3,751)	Hispanic (n=4,090)	Tests	P-value
Length of Hospital Stay	1.85 ± 2.01	1.88 ± 2.02	1.86 ± 1.98	1.83 ± 2.04	F-test: 0.75	0.474
Readmissions	107 (0.99%)	27 (0.84%)	38 (1.01%)	42 (1.03%)	Chi2: 0.752	0.687

Model adjusted for age, sex, insurance type, pre-existing comorbidity, obesity classification and geographic classification.

Table 4: Adjusted association between DCI Quintiles, Race & Ethnicity and length of hospital stay, Maryland 2018–2020

Length of Hospital Stay	Coef.	95% CI		P>t
Distressed Communities Index				
Prosperous	Reference			
Comfortable	0.011	-0.091	0.113	0.833
Mid-Tier	0.055	-0.057	0.167	0.334
At-Risk	-0.017	-0.142	0.109	0.792
Distressed	-0.048	-0.205	0.108	0.547
Race & Ethnicity				
White	Reference			
Black	0.085	0.001	0.169	0.046
Hispanic	0.036	-0.145	0.218	0.695
Other	0.119	-0.134	0.372	0.357

Model adjusted for age, sex, insurance type, pre-existing comorbidity, obesity classification and geographic context

Table 5: Adjusted Odds of Readmission by DCI Quintiles, Race & Ethnicity, Maryland 2018–2020

Readmission	Odds Ratio	95% CI		P>z
Distressed Communities Index				
Prosperous	Reference			
Comfortable	1.52	0.841	2.748	0.165
Mid-Tier	1.739	0.928	3.258	0.084
At-Risk	1.209	0.581	2.518	0.611
Distressed	1.409	0.649	3.059	0.386
Race & Ethnicity				
White	Reference			
Black	0.767	0.489	1.204	0.249
Hispanic	1.39	0.576	3.353	0.464
Other	0.439	0.06	3.228	0.418

Model adjusted for age, sex, insurance type, pre-existing comorbidity, obesity classification and geographic context

Table 6: Marginal Effects of Race & Ethnicity on Hospital Stay following Bariatric Surgery by DCI, Maryland 2018–2020

		Marginal Effects	95% CI		P>t
Black vs. White	**Distressed Communities Index**				
	Prosperous	7.6%	-8.8%	24.0%	0.364
	Comfortable	15.0%	6.0%	29.5%	**0.041**
	Mid-Tier	12.4%	-5.3%	30.2%	0.170
	At-Risk	6.5%	-14.3%	27.3%	0.541
	Distressed	-16.7%	-41.8%	8.4%	0.192
Hispanic vs. Other	**Distressed Communities Index**				
	Prosperous	7.0%	-36.6%	38.1%	0.971
	Comfortable	25.1%	-8.9%	59.1%	0.148
	Mid-Tier	-7.0%	-40.4%	26.5%	0.684
	At-Risk	-7.8%	-55.8%	40.3%	0.751
	Distressed	6.4%	-69.7%	82.5%	0.869
Other vs. White	**Distressed Communities Index**				
	Prosperous	17.2%	-25.3%	59.7%	0.427
	Comfortable	0.000	-43.9%	43.8%	0.999
	Mid-Tier	62.4%	-1.5%	126.3%	0.056
	At-Risk	-15.5%	-90.1%	59.1%	0.684
	Distressed	-36.4%	-152.7%	79.8%	0.539

Marginal effects (with 95% confidence intervals) of race and ethnicity (Black, Hispanic, and Other vs. White) on the likelihood of prolonged hospital stay following bariatric surgery, stratified by neighborhood socioeconomic status (DCI quintiles). Estimates represent the percentage point difference in predicted probability of extended hospital stay for each racial or ethnic group compared to White patients within each DCI category. Positive values indicate a higher probability of prolonged stay; negative values indicate a lower probability.

Table 7: Marginal Effects of Race (Black vs. White) on Readmissions following Bariatric

Surgery by DCI, Maryland 2018–2020

Distressed Communities Index	Marginal Effects	95% CI		p-value
Prosperous	0.30%	-0.50%	1.10%	0.51
Comfortable	-0.50%	-1.30%	-0.40%	0.26
Mid-Tier	-0.90%	-2.00%	0.30%	0.13
At-Risk	0.00%	-0.90%	1.00%	0.92
Distressed	-0.40%	-1.50%	0.80%	0.49

Marginal effects (with 95% confidence intervals) of race (Black vs. White) on the likelihood of 30-day hospital readmissions following bariatric surgery, stratified by neighborhood socioeconomic status (Distressed Communities Index quintiles). Estimates represent the percentage point difference in the predicted probability of readmission for Black patients compared to White patients within each DCI category. Positive values indicate a higher probability of readmission; negative values indicate a lower probability.

Chapter 5: Conclusion

Study Summary

This dissertation examined the influence of neighborhood socioeconomic status (nSES), measured by the Distressed Communities Index (DCI), on the utilization and short-term outcomes following bariatric surgery among adult patients in Maryland. Three distinct yet interconnected studies were conducted to assess how socioeconomic disparities at the neighborhood level impact healthcare utilization and postoperative outcomes for bariatric surgery patients.

The first study evaluated the association between neighborhood socioeconomic status and bariatric surgery utilization. It demonstrated significant disparities, finding that patients residing in socioeconomically distressed neighborhoods were considerably less likely to undergo bariatric surgery compared to those from more affluent neighborhoods. Specifically, individuals from distressed neighborhoods had 33% lower odds of receiving bariatric surgery compared to those from prosperous areas. Across all DCI quintiles, Black individuals had higher bariatric surgery utilization than White individuals, a pattern not observed among Hispanic or Other racial groups.

The second study investigated the impact of neighborhood socioeconomic status on short-term postoperative complications following bariatric surgery. Contrary to expectations, this study found no statistically significant association between neighborhood socioeconomic disadvantage, as measured by the Distressed Communities Index, and short-term postoperative complications such as gastrointestinal leaks, venous thromboembolism, or gastrointestinal bleeding. We created a composite outcome to capture whether a patient experienced any postoperative complication. There was no significant association between DCI quintiles and the risk of experiencing at least

one complication following bariatric surgery. Additionally, race & ethnicity did not significantly moderate this relationship, suggesting that standardized perioperative protocols and Maryland's All-Payer Model may mitigate some socioeconomic disparities in short-term surgical outcomes.

The third study assessed whether neighborhood socioeconomic status influenced healthcare quality measures, specifically hospital length of stay and readmission rates following bariatric surgery. DCI quintiles were not significantly associated with readmissions or prolonged hospital stay after bariatric surgery.

Study Limitations

Several limitations across the three studies should be acknowledged. Firstly, utilizing ZIP codes to measure neighborhood socioeconomic status via the Distressed Communities Index assumes homogeneity in socioeconomic conditions within each ZIP code. This assumption likely does not capture the variability of individual-level socioeconomic factors within neighborhoods, such as specific income levels, educational attainment, employment status, or healthcare access, all of which may independently affect bariatric surgery utilization and outcomes.

Additionally, reliance on administrative data from the Maryland State Inpatient Database (SID) presents inherent limitations, including potential misclassification bias due to reliance on ICD-10 codes rather than clinical validation. Administrative databases typically lack comprehensive clinical details, such as severity of obesity-related conditions, nutritional status, social support systems, adherence to postoperative care instructions, and healthcare literacy, potentially leading to unmeasured confounding.

Another limitation is the observational study design, which precludes definitive causal inference. While associations between neighborhood socioeconomic status and surgery outcomes were

observed, the nature of retrospective cohort and cross-sectional analyses cannot establish causality. Hospital-level factors, such as variations in care quality, provider experience, and facility resources, which could independently influence outcomes, were not assessed.

The use of administrative inpatient databases inherently excludes outpatient care, which is particularly relevant given increasing trends toward outpatient bariatric procedures. This exclusion limits the understanding of how outpatient care influences postoperative outcomes and healthcare utilization disparities. Although restricting the analysis to inpatient procedures partially mitigates this concern, the potential impact of outpatient care remains unaddressed.

The substantial missing data (approximately 40%) for the primary explanatory variable, DCI, necessitated multiple imputation techniques. Although sensitivity analyses confirmed the robustness of findings, multiple imputation inherently introduces uncertainty and could potentially bias the estimates.

Lastly, the generalizability of findings may be limited by Maryland's unique All-Payer Model, which standardizes hospital reimbursement rates. This model may mitigate financial disparities in healthcare access compared to other states, potentially limiting the applicability of results to states without similar reimbursement systems.

Future research should consider integrating longitudinal designs, individual-level socioeconomic data, patient-reported outcomes, and qualitative methods to provide a more comprehensive understanding of the factors influencing bariatric surgery utilization and outcomes.

Study Conclusions

Collectively, the findings of this dissertation underscore the critical role of neighborhood socioeconomic status as a determinant of bariatric surgery utilization. While neighborhood disadvantage was consistently associated with lower utilization rates, it did not significantly influence immediate postoperative complication rates, readmissions, or hospital stays. These nuanced outcomes suggest that broader systemic factors, including standardized healthcare protocols under Maryland's All-Payer Model, might attenuate immediate postoperative disparities in Maryland.

This research highlights the need for targeted interventions addressing barriers to healthcare access in disadvantaged neighborhoods, including enhancing post-discharge support systems, improving healthcare literacy, and refining referral and follow-up procedures. Moreover, policy efforts aimed at reducing structural inequities within healthcare systems, particularly those targeting neighborhood-level disparities, are crucial for achieving equitable surgical care outcomes.

Ultimately, addressing socioeconomic disparities in healthcare requires comprehensive, systemic changes aimed at enhancing social support structures, economic empowerment, and equitable resource allocation to disadvantaged communities. Future studies should further explore long-term outcomes and investigate specific mechanisms by which neighborhood-level factors influence healthcare access and quality to inform effective health policy interventions.

Appendix A: UMD Institutional Approval

UNIVERSITY OF MARYLAND

INSTITUTIONAL REVIEW BOARD

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DATE:	March 6, 2025
TO:	Oluwasegun Akinyemi, MD, MSc.
FROM:	University of Maryland College Park (UMCP) IRB
PROJECT TITLE:	[2284677-1] Neighborhood Socioeconomic Status, Utilization and Short-Term Post-Operative Outcomes Following Bariatric Surgery in Maryland
SUBMISSION TYPE:	New Project
ACTION:	DETERMINATION OF EXEMPT STATUS
DECISION DATE:	March 6, 2025
REVIEW CATEGORY:	Exemption category # 45CFR46.104(d)(4)(ii)

Thank you for your submission of New Project materials for this project. The University of Maryland College Park (UMCP) IRB has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will retain a copy of this correspondence within our records.

If you have any questions, please contact the IRB Office at 301-405-4212 or irb@umd.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Maryland College Park (UMCP) IRB's records.

- 1 -   Generated on IRBNet

Appendix B: Sensitivity Analysis Results

Table 1: Adjusted odds of Post-op Complications following Bariatric Surgery by ADI Strata and Race, Maryland 2018–2020

Bariatric Surgery Utilization	Odds Ratio	95% CI		P>z
Area Deprivation Index				
<25th Percentile	Reference			
25th-75th Percentile	0.874	0.828	0.923	<0.001
>75th Percentile	0.958	0.905	1.014	0.136
Race & Ethnicity				
White	Reference			
Black	1.271	1.213	1.332	<0.001
Hispanic	1.093	0.985	1.212	0.093
Other	1.023	0.885	1.181	0.76

Table 1 displays adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for post-operative complications following bariatric surgery by Area Deprivation Index (ADI) strata and race/ethnicity in Maryland from 2018 to 2020. Estimates are derived from multivariable logistic regression models adjusting for demographic and clinical covariates. The <25th ADI percentile and White race serve as reference groups.

Table 2: Adjusted odds of Post-op Complications following Bariatric Surgery by ADI Strata and Race, Maryland 2018–2020

All Complications	All Complication	GIT Leaks	Venous Thromboembolism	GIT Bleeding
Area Deprivation Index				
<25th Percentile	Reference	Reference	Reference	Reference
25th-75th Percentile	1.00 (0.81-1.24)	0.79 (0.48-1.28)	1.24 (0.90-1.72)	1.00 (0.52-1.93)
>75th Percentile	0.85 (0.67-1.07)	0.69 (0.40-1.89)	0.86 (0.59-1.23)	1.23 (0.63-2.40)
Race & Ethnicity				

White	Reference	Reference	Reference	Reference
Black	0.98 (0.81-1.19)	1.05 (0.66-1.67)	1.00 (0.75-1.34)	1.46 (0.82-2.59)
Hispanic	1.16 (0.76-1.77)	2.22 (1.05-4.72)	0.93 (0.44-1.93)	1.54 (0.45-5.26)
Other	0.73 (0.37-1.45)	-	1.05 (0.42-2.61)	0.97 (0.13-7.26)

Table 2 presents adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for various post-operative complications following bariatric surgery, stratified by Area Deprivation Index (ADI) and race/ethnicity, in Maryland from 2018 to 2020. Complications assessed include overall complications, gastrointestinal (GIT) leaks, venous thromboembolism, and GIT bleeding. Estimates were obtained from multivariable logistic regression models adjusting for relevant demographic and clinical factors. The <25th ADI percentile and White race serve as reference categories. A dash (–) indicates insufficient sample size for model estimation.

Table 3: Adjusted Odds of 30-day Readmission by ADI Strata, Race & Ethnicity, Maryland 2018–2020

Readmission	Odds Ratio	95% CI		P>z
Area Deprivation Index				
<25th Percentile	Reference			
25th-75th Percentile	1.164	0.7	1.935	0.558
>75th Percentile	0.877	0.505	1.521	0.64
Race & Ethnicity				
White	Reference			
Black	0.812	0.52	1.266	0.358
Hispanic	1.445	0.601	3.476	0.411
Other	0.429	0.058	3.161	0.406

Table 3 shows adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for 30-day hospital readmission following bariatric surgery, stratified by Area Deprivation Index (ADI) and race/ethnicity, in Maryland from 2018 to 2020. Estimates are derived from multivariable logistic regression models accounting for key demographic and clinical covariates. The <25th ADI percentile and White race serve as reference groups.

Table 4: Adjusted association between ADI Strata, Race & Ethnicity and length of hospital stay, Maryland 2018–2020

Length of Hospital Stay	Coef.	95% CI		P>t
Area Deprivation Index				
<25th Percentile	Reference			
25th-75th Percentile	-0.016	-0.111	0.078	0.737
>75th Percentile	-0.073	-0.172	0.026	0.149

Race & Ethnicity				
White	Reference			
Black	0.091	0.008	0.174	0.032
Hispanic	0.036	-0.145	0.217	0.698
Other	0.111	-0.141	0.364	0.388

Table 4 presents adjusted coefficients and 95% confidence intervals (CIs) for the association between Area Deprivation Index (ADI) strata, race/ethnicity, and length of hospital stay following bariatric surgery in Maryland from 2018 to 2020. Estimates are derived from multivariable linear regression models adjusting for relevant demographic and clinical characteristics. The <25th ADI percentile and White race serve as reference groups.

Appendix C: STATA ANALYSIS CODES FOR PAPER 1

*********Study I*********
********Patient Selection******

********Body Mass Index Code**********

```
gen Obesity_Class = 0
forvalues c=1/35 {
replace Obesity_Class = 1 if I10_DX`c' == "Z6830" | I10_DX`c' == "Z6831" | I10_DX`c' == "Z6832"
replace Obesity_Class = 1 if I10_DX`c' == "Z6833" | I10_DX`c' == "Z6834"
replace Obesity_Class = 2 if I10_DX`c' == "Z6835" | I10_DX`c' == "Z6836" | I10_DX`c' == "Z6837"
replace Obesity_Class = 2 if I10_DX`c' == "Z6838" | I10_DX`c' == "Z6839"
replace Obesity_Class = 3 if I10_DX`c' == "Z6841" | I10_DX`c' == "Z6842" | I10_DX`c' == "Z6843"
replace Obesity_Class = 3 if I10_DX`c' == "Z6844" | I10_DX`c' == "Z6845"
}
*******drop Obesity Class I: BMI 30.0-34.9*****
drop if Obesity_Class==1
```

********generate Bariatric surgery procedures codes*******

```
gen BS=0
forvalues c=1/25 {
replace BS=1 if
I10_PR`c'=="0DB64Z3"|I10_PR`c'=="0DV64CZ"|I10_PR`c'=="0D16479"|I10_PR`c'=="0D1647A"|I10_PR`c'=="0D1647B"
replace BS=1 if
I10_PR`c'=="0D1647L"|I10_PR`c'=="0D164J9"|I10_PR`c'=="0D164JA"|I10_PR`c'=="0D164JB"|I10_PR`c'=="0D164JL"
replace BS=1 if
I10_PR`c'=="0D164K9"|I10_PR`c'=="0D164KA"|I10_PR`c'=="0D164KB"|I10_PR`c'=="0D164KL"|I10_PR`c'=="0D164Z9"
replace BS=1 if I10_PR`c'=="0D164ZA"|I10_PR`c'=="0D164ZB"|I10_PR`c'=="0D164ZL"
replace BS=1 if
I10_PR`c'=="0D16079"|I10_PR`c'=="0D1607A"|I10_PR`c'=="0D1607B"|I10_PR`c'=="0D1607L"|I10_PR`c'=="0D160J9"
```

```
replace BS=1 if
I10_PR`c'=="0D160JA"|I10_PR`c'=="0D160JB"|I10_PR`c'=="0D160JL"|I10_PR`c'=="0D160K9"|I10_PR`c'=="0D160KA"
replace BS=1 if
I10_PR`c'=="0D160KB"|I10_PR`c'=="0D160KL"|I10_PR`c'=="0D160Z9"|I10_PR`c'=="0D160ZA"|I10_PR`c'=="0D160ZB"
replace BS=1 if
I10_PR`c'=="0D160ZL"|I10_PR`c'=="0D16879"|I10_PR`c'=="0D1687A"|I10_PR`c'=="0D1687B"|I10_PR`c'=="0D1687L"
replace BS=1 if
I10_PR`c'=="0D168J9"|I10_PR`c'=="0D168JA"|I10_PR`c'=="0D168JB"|I10_PR`c'=="0D168JL"|I10_PR`c'=="0D168K9"
replace BS=1 if
I10_PR`c'=="0D168KA"|I10_PR`c'=="0D168KB"|I10_PR`c'=="0D168KL"|I10_PR`c'=="0D168Z9"|I10_PR`c'=="0D168ZA"
replace BS=1 if I10_PR`c'=="0D168ZB"|I10_PR`c'=="0D168ZL"
replace BS=1 if
I10_PR`c'=="0D19079"|I10_PR`c'=="0D1907A"|I10_PR`c'=="0D1907B"|I10_PR`c'=="0D190J9"|I10_PR`c'=="0D190JA"
replace BS=1 if
I10_PR`c'=="0D190JB"|I10_PR`c'=="0D190K9"|I10_PR`c'=="0D190KA"|I10_PR`c'=="0D190KB"|I10_PR`c'=="0D190Z9"
replace BS=1 if
I10_PR`c'=="0D190ZA"|I10_PR`c'=="0D190ZB"|I10_PR`c'=="0D19479"|I10_PR`c'=="0D1947A"|I10_PR`c'=="0D1947B"
replace BS=1 if
I10_PR`c'=="0D194J9"|I10_PR`c'=="0D194JA"|I10_PR`c'=="0D194JB"|I10_PR`c'=="0D194K9"|I10_PR`c'=="0D194KA"
replace BS=1 if
I10_PR`c'=="0D194KB"|I10_PR`c'=="0D194Z9"|I10_PR`c'=="0D194ZA"|I10_PR`c'=="0D194ZB"|I10_PR`c'=="0D19879"
replace BS=1 if
I10_PR`c'=="0D1987A"|I10_PR`c'=="0D1987B"|I10_PR`c'=="0D198J9"|I10_PR`c'=="0D198JA"|I10_PR`c'=="0D198JB"
replace BS=1 if
I10_PR`c'=="0D198K9"|I10_PR`c'=="0D198KA"|I10_PR`c'=="0D198KB"|I10_PR`c'=="0D198Z9"|I10_PR`c'=="0D198ZA"
replace BS=1 if
I10_PR`c'=="0D198ZB"|I10_PR`c'=="0D1A07A"|I10_PR`c'=="0D1A07B"|I10_PR`c'=="0D1A0JA"|I10_PR`c'=="0D1A0JB"
replace BS=1 if
I10_PR`c'=="0D1A0KA"|I10_PR`c'=="0D1A0KB"|I10_PR`c'=="0D1A0ZA"|I10_PR`c'=="0D1A0ZB"|I10_PR`c'=="0D1A47A"
replace BS=1 if
I10_PR`c'=="0D1A47B"|I10_PR`c'=="0D1A4JA"|I10_PR`c'=="0D1A4JB"|I10_PR`c'=="0D1A4KA"|I10_PR`c'=="0D1A4KB"
replace BS=1 if
I10_PR`c'=="0D1A4ZA"|I10_PR`c'=="0D1A4ZB"|I10_PR`c'=="0D1A87A"|I10_PR`c'=="0D1A87B"|I10_PR`c'=="0D1A8JA"
```

```
replace BS=1 if
I10_PR`c'=="0D1A8JB"|I10_PR`c'=="0D1A8KA"|I10_PR`c'=="0D1A8KB"|I10_PR`c'=="0D1A8ZA"|I10_PR`c'=="0D1A8ZB"
replace BS=1 if
I10_PR`c'=="0D1A8ZH"|I10_PR`c'=="0D1B07B"|I10_PR`c'=="0D1B0JB"|I10_PR`c'=="0D1B0KB"|I10_PR`c'=="0D1B0ZB"
replace BS=1 if
I10_PR`c'=="0D1B47B"|I10_PR`c'=="0D1B4JB"|I10_PR`c'=="0D1B4KB"|I10_PR`c'=="0D1B4ZB"|I10_PR`c'=="0D1B87B"
replace BS=1 if I10_PR`c'=="0D1B8JB"|I10_PR`c'=="0D1B8KB"|I10_PR`c'=="0D1B8ZB"|I10_PR`c'=="0D1B8ZH"
replace BS=1 if
I10_PR`c'=="0DB60Z3"|I10_PR`c'=="0DB60ZZ"|I10_PR`c'=="0DB63Z3"|I10_PR`c'=="0DB63ZZ"|I10_PR`c'=="0DB67Z3"
replace BS=1 if
I10_PR`c'=="0DB67ZZ"|I10_PR`c'=="0DB68Z3"|I10_PR`c'=="0DB80ZZ"|I10_PR`c'=="0DB90ZZ"|I10_PR`c'=="0DBB0ZZ"
replace BS=1 if I10_PR`c'=="0D160ZB"|I10_PR`c'=="0F190Z3"
}


gen RACE4=.
replace RACE4=0 if RACE==1
replace RACE4=1 if RACE==2
replace RACE4=2 if RACE==3
replace RACE4=3 if RACE==4|RACE==5|RACE==6
tab RACE4
label define RACE4 0 "White" 1 "Black" 2 "Hispanic" 3 "Other"
label values RACE4 RACE4

codebook PAY1
gen Insurance=.
replace Insurance=0 if PAY1=4
replace Insurance=0 if PAY1==4
replace Insurance=1 if PAY1==1
replace Insurance=2 if PAY1==2
replace Insurance=3 if PAY1==3
replace Insurance=4 if PAY1==6
tab Insurance
```

```
label define Insurance 0 "Self-Pay" 1 "Medicare" 2 "Mediciad" 3 "Private" 4 "Other"
label values Insurance Insurance

sum AGE,detail
recode AGE 18/44=0 45/64=1 65/200=2, prefix(new_age2)
tab new_age2AGE
drop if new_age2AGE > 2
tab new_age2AGE
label define AGE2 0 "18/44Yr." 1 "45/64Yr." 2 ">64Yr."
label values new_age2AGE AGE2
rename new_age2AGE AGE2

gen diabetes=0
forvalues c=1/25 {
replace diabetes=1 if I10_DX`c'=="E090" | I10_DX`c'=="E11"  | I10_DX`c'=="E111" | I10_DX`c'=="E1101" | I10_DX`c'=="E1110" |
I10_DX`c'=="E1111"
replace diabetes=1 if I10_DX`c'=="E1121"| I10_DX`c'=="E1122"| I10_DX`c'=="E1129" | I10_DX`c'=="E113" | I10_DX`c'=="E114"
| I10_DX`c'=="E115"
replace diabetes=1 if I10_DX`c'=="E116" | I10_DX`c'=="E118" | I10_DX`c'=="E119" | I10_DX`c'=="E13" | I10_DX`c'=="E130" |
I10_DX`c'=="E131"
replace diabetes=1 if I10_DX`c'=="E132" | I10_DX`c'=="E133" | I10_DX`c'=="E134" | I10_DX`c'=="E125" | I10_DX`c'=="E136" |
I10_DX`c'=="E138"
replace diabetes=1 if I10_DX`c'=="E139" | I10_DX`c'=="E10"  | I10_DX`c'=="E1010" | I10_DX`c'=="E1011" | I10_DX`c'=="E103" |
I10_DX`c'=="E1032"
replace diabetes=1 if I10_DX`c'=="E1033"| I10_DX`c'=="E1035"| I10_DX`c'=="E104" | I10_DX`c'=="E105" | I10_DX`c'=="E106" |
I10_DX`c'=="E108"
replace diabetes=1 if I10_DX`c'=="E109"
}

gen heart_failure=0
forvalues c=1/15 {
replace heart_failure=1 if I10_DX`c'=="I110" | I10_DX`c'=="I50810" | I10_DX`c'=="I509" | I10_DX`c'=="I50811"
replace heart_failure=1 if I10_DX`c'=="I50812" | I10_DX`c'=="I50814" | I10_DX`c'=="I5021" | I10_DX`c'=="I5022"
```

```
replace heart_failure=1 if I10_DX`c'=="I5031" | I10_DX`c'=="I5032" | I10_DX`c'=="I502" | I10_DX`c'=="I5084"
replace heart_failure=1 if I10_DX`c'=="I503" | I10_DX`c'=="I5020" | I10_DX`c'=="I5030" | I10_DX`c'=="I5023"
replace heart_failure=1 if I10_DX`c'=="I5033" | I10_DX`c'=="I50183" | I10_DX`c'=="I504" | I10_DX`c'=="I5041"
replace heart_failure=1 if I10_DX`c'=="I5042" | I10_DX`c'=="I5043" | I10_DX`c'=="I5081" | I10_DX`c'=="I5082"
replace heart_failure=1 if I10_DX`c'=="I501"
}

gen hypertension=0
forvalues c=1/25 {
replace hypertension=1 if I10_DX`c'=="I10" | I10_DX`c'=="I15" | I10_DX`c'=="I150" | I10_DX`c'=="I151"
replace hypertension=1 if I10_DX`c'=="I152" | I10_DX`c'=="I158" | I10_DX`c'=="I159" | I10_DX`c'=="I160"
replace hypertension=1 if I10_DX`c'=="I161" | I10_DX`c'=="I674"
}

gen hyperlipidemia=0
forvalues c=1/25 {
replace hyperlipidemia=1 if I10_DX`c'=="E7800" | I10_DX`c'=="E7801" | I10_DX`c'=="E781" | I10_DX`c'=="E782"
replace hyperlipidemia=1 if I10_DX`c'=="E783" | I10_DX`c'=="E784" | I10_DX`c'=="E7849" | I10_DX`c'=="E785"
replace hyperlipidemia=1 if I10_DX`c'=="E786" | I10_DX`c'=="E787" | I10_DX`c'=="E788"
}
gen ckd=0
forvalues c=1/25 {
replace ckd=1 if I10_DX`c'=="N181" | I10_DX`c'=="N182" | I10_DX`c'=="N183" | I10_DX`c'=="N184"
replace ckd=1 if I10_DX`c'=="N185" | I10_DX`c'=="N186" | I10_DX`c'=="N189" | I10_DX`c'=="I120"
replace ckd=1 if I10_DX`c'=="I12" | I10_DX`c'=="I129" | I10_DX`c'=="E0822" | I10_DX`c'=="E0922"
replace ckd=1 if I10_DX`c'=="E1022" | I10_DX`c'=="E1122" | I10_DX`c'=="E112"
}
gen copd=0
forvalues c=1/25 {
replace copd=1 if I10_DX`c'=="J449" | I10_DX`c'=="J43" | I10_DX`c'=="J430" | I10_DX`c'=="J431"
replace copd=1 if I10_DX`c'=="J432" | I10_DX`c'=="J438" | I10_DX`c'=="J439" | I10_DX`c'=="J44"
replace copd=1 if I10_DX`c'=="J440" | I10_DX`c'=="J441" | I10_DX`c'=="J449" | I10_DX`c'=="J41"
replace copd=1 if I10_DX`c'=="J410" | I10_DX`c'=="J411" | I10_DX`c'=="J418"
```

```
}

gen ischemic_cvd=0
forvalues c=1/25 {
replace ischemic_cvd=1 if I10_DX`c'=="Z8673" | I10_DX`c'=="I639" | I10_DX`c'=="I6340" | I10_DX`c'=="I63"
replace ischemic_cvd=1 if I10_DX`c'=="I6330" | I10_DX`c'=="I6300" | I10_DX`c'=="I63019" | I10_DX`c'=="I6309"
replace ischemic_cvd=1 if I10_DX`c'=="I6310" | I10_DX`c'=="I63113" | I10_DX`c'=="I63111" | I10_DX`c'=="I63119"
replace ischemic_cvd=1 if I10_DX`c'=="I63349" | I10_DX`c'=="I63449"
}
tab ischemic_cvd

tab diabetes
tab hypertension
gen atrial_fibrillation=0
forvalues c=1/25 {
replace atrial_fibrillation=1 if I10_DX`c'=="I480" | I10_DX`c'=="I4891" | I10_DX`c'=="I4819" | I10_DX`c'=="I4820"
replace atrial_fibrillation=1 if I10_DX`c'=="I489" | I10_DX`c'=="I481" | I10_DX`c'=="I48" | I10_DX`c'=="I4811"
replace atrial_fibrillation=1 if I10_DX`c'=="I483" | I10_DX`c'=="I4821" | I10_DX`c'=="I484" | I10_DX`c'=="I483"
}
tab atrial_fibrillation

gen smoking_tobacco_use=0
forvalues c=1/25 {
replace smoking_tobacco_use=1 if I10_DX`c'=="Z87891" | I10_DX`c'=="Z720" | I10_DX`c'=="F172" | I10_DX`c'=="F17220"
}
rename smoking_tobacco_use
rename smoking_tobacco_use smoking

}
gen solid_cancer=0
forvalues c=1/25 {
replace solid_cancer=1 if I10_DX`c'=="C000" | I10_DX`c'=="C001" | I10_DX`c'=="C002" | I10_DX`c'=="C003"
```

```
replace solid_cancer=1 if I10_DX`c'=="C004" | I10_DX`c'=="C005" | I10_DX`c'=="C006" | I10_DX`c'=="C008" |
I10_DX`c'=="C009"
replace solid_cancer=1 if I10_DX`c'=="C01" | I10_DX`c'=="C020" | I10_DX`c'=="C021" | I10_DX`c'=="C022" |
I10_DX`c'=="C023"
replace solid_cancer=1 if I10_DX`c'=="C024" | I10_DX`c'=="C028" | I10_DX`c'=="C029" | I10_DX`c'=="C030" |
I10_DX`c'=="C031"
replace solid_cancer=1 if I10_DX`c'=="C039" | I10_DX`c'=="C040" | I10_DX`c'=="C041" | I10_DX`c'=="C048" |
I10_DX`c'=="C049"
replace solid_cancer=1 if I10_DX`c'=="C050" | I10_DX`c'=="C051" | I10_DX`c'=="C052" | I10_DX`c'=="C058" |
I10_DX`c'=="C059"
replace solid_cancer=1 if I10_DX`c'=="C060" | I10_DX`c'=="C061" | I10_DX`c'=="C062" | I10_DX`c'=="C0680" |
I10_DX`c'=="C0689"
replace solid_cancer=1 if I10_DX`c'=="C069" | I10_DX`c'=="C07" | I10_DX`c'=="C080" | I10_DX`c'=="C081" |
I10_DX`c'=="C089"
replace solid_cancer=1 if I10_DX`c'=="C090" | I10_DX`c'=="C091" | I10_DX`c'=="C098" | I10_DX`c'=="C099" |
I10_DX`c'=="C100"
replace solid_cancer=1 if I10_DX`c'=="C101" | I10_DX`c'=="C102" | I10_DX`c'=="C103" | I10_DX`c'=="C104" |
I10_DX`c'=="C108"
replace solid_cancer=1 if I10_DX`c'=="C109" | I10_DX`c'=="C110" | I10_DX`c'=="C111" | I10_DX`c'=="C112" |
I10_DX`c'=="C113"
replace solid_cancer=1 if I10_DX`c'=="C118" | I10_DX`c'=="C119" | I10_DX`c'=="C153" | I10_DX`c'=="C154" |
I10_DX`c'=="C155"
replace solid_cancer=1 if I10_DX`c'=="C158" | I10_DX`c'=="C159" | I10_DX`c'=="C160" | I10_DX`c'=="C161" |
I10_DX`c'=="C162"
replace solid_cancer=1 if I10_DX`c'=="C163" | I10_DX`c'=="C164" | I10_DX`c'=="C165" | I10_DX`c'=="C166" |
I10_DX`c'=="C168"
replace solid_cancer=1 if I10_DX`c'=="C169" | I10_DX`c'=="C170" | I10_DX`c'=="C171" | I10_DX`c'=="C172" |
I10_DX`c'=="C173"
replace solid_cancer=1 if I10_DX`c'=="C178" | I10_DX`c'=="C179" | I10_DX`c'=="C180" | I10_DX`c'=="C181" |
I10_DX`c'=="C182"
replace solid_cancer=1 if I10_DX`c'=="C183" | I10_DX`c'=="C184" | I10_DX`c'=="C185" | I10_DX`c'=="C186" |
I10_DX`c'=="C187"
replace solid_cancer=1 if I10_DX`c'=="C188" | I10_DX`c'=="C189" | I10_DX`c'=="C19" | I10_DX`c'=="C20" | I10_DX`c'=="C210"
```

```
replace solid_cancer=1 if I10_DX`c'=="C211" | I10_DX`c'=="C212" | I10_DX`c'=="C218" | I10_DX`c'=="C220" |
I10_DX`c'=="C221"
replace solid_cancer=1 if I10_DX`c'=="C222" | I10_DX`c'=="C223" | I10_DX`c'=="C224" | I10_DX`c'=="C227" |
I10_DX`c'=="C228"
replace solid_cancer=1 if I10_DX`c'=="C229" | I10_DX`c'=="C23" | I10_DX`c'=="C240" | I10_DX`c'=="C241" |
I10_DX`c'=="C248"
replace solid_cancer=1 if I10_DX`c'=="C249" | I10_DX`c'=="C250" | I10_DX`c'=="C251" | I10_DX`c'=="C252" |
I10_DX`c'=="C253"
replace solid_cancer=1 if I10_DX`c'=="C254" | I10_DX`c'=="C257" | I10_DX`c'=="C258" | I10_DX`c'=="C259" |
I10_DX`c'=="C300"
replace solid_cancer=1 if I10_DX`c'=="C301" | I10_DX`c'=="C310" | I10_DX`c'=="C311" | I10_DX`c'=="C312" |
I10_DX`c'=="C313"
replace solid_cancer=1 if I10_DX`c'=="C318" | I10_DX`c'=="C319" | I10_DX`c'=="C33" | I10_DX`c'=="C3400" |
I10_DX`c'=="C3401"
replace solid_cancer=1 if I10_DX`c'=="C3412" | I10_DX`c'=="C342" | I10_DX`c'=="C3430" | I10_DX`c'=="C3431" |
I10_DX`c'=="C3432"
replace solid_cancer=1 if I10_DX`c'=="C3480" | I10_DX`c'=="C3481" | I10_DX`c'=="C3482" | I10_DX`c'=="C3490" |
I10_DX`c'=="C3491"
replace solid_cancer=1 if I10_DX`c'=="C3492" | I10_DX`c'=="C50011" | I10_DX`c'=="C50012" | I10_DX`c'=="C50019" |
I10_DX`c'=="C50021"
}
tab solid_cancer

gen liver_disease=0
forvalues c=1/25 {
replace liver_disease=1 if I10_DX`c'=="K762" | I10_DX`c'=="K763" | I10_DX`c'=="K764" | I10_DX`c'=="K765"
replace liver_disease=1 if I10_DX`c'=="K766" | I10_DX`c'=="K767" | I10_DX`c'=="K768" | I10_DX`c'=="K7681"
replace liver_disease=1 if I10_DX`c'=="K7682" | I10_DX`c'=="K7689" | I10_DX`c'=="K769" | I10_DX`c'=="K77"
replace liver_disease=1 if I10_DX`c'=="K80" | I10_DX`c'=="K800" | I10_DX`c'=="K8000" | I10_DX`c'=="K8001"
replace liver_disease=1 if I10_DX`c'=="K801" | I10_DX`c'=="K8010" | I10_DX`c'=="K8011" | I10_DX`c'=="K8012"
replace liver_disease=1 if I10_DX`c'=="K8013"
}
gen paralysis=0
```

```
forvalues c=1/25 {
replace paralysis=1 if I10_DX`c'=="G8113" | I10_DX`c'=="G8114" | I10_DX`c'=="G819" | I10_DX`c'=="G8190"
replace paralysis=1 if I10_DX`c'=="G8191" | I10_DX`c'=="G8192" | I10_DX`c'=="G8193" | I10_DX`c'=="G8194"
replace paralysis=1 if I10_DX`c'=="G82" | I10_DX`c'=="G822" | I10_DX`c'=="G8220" | I10_DX`c'=="G8221"
replace paralysis=1 if I10_DX`c'=="G8222" | I10_DX`c'=="G825" | I10_DX`c'=="G8250" | I10_DX`c'=="G8251"
replace paralysis=1 if I10_DX`c'=="G8252" | I10_DX`c'=="G8253" | I10_DX`c'=="G8254" | I10_DX`c'=="G83"
replace paralysis=1 if I10_DX`c'=="G830"
}
gen hiv_aids=0
forvalues c=1/25 {
replace hiv_aids=1 if I10_DX`c'=="B20" | I10_DX`c'=="B200" | I10_DX`c'=="B201" | I10_DX`c'=="B202"
replace hiv_aids=1 if I10_DX`c'=="B203" | I10_DX`c'=="B204" | I10_DX`c'=="B205" | I10_DX`c'=="B206"
replace hiv_aids=1 if I10_DX`c'=="B207" | I10_DX`c'=="B208" | I10_DX`c'=="B209" | I10_DX`c'=="B21"
replace hiv_aids=1 if I10_DX`c'=="B210" | I10_DX`c'=="B211" | I10_DX`c'=="B212" | I10_DX`c'=="B213"
replace hiv_aids=1 if I10_DX`c'=="B217" | I10_DX`c'=="B218" | I10_DX`c'=="B219" | I10_DX`c'=="B22"
replace hiv_aids=1 if I10_DX`c'=="B220" | I10_DX`c'=="B221" | I10_DX`c'=="B222" | I10_DX`c'=="B227"
replace hiv_aids=1 if I10_DX`c'=="B23" | I10_DX`c'=="B230" | I10_DX`c'=="B231" | I10_DX`c'=="B232"
replace hiv_aids=1 if I10_DX`c'=="B238" | I10_DX`c'=="B24" | I10_DX`c'=="O987" | I10_DX`c'=="R75"
replace hiv_aids=1 if I10_DX`c'=="Z114" | I10_DX`c'=="Z206" | I10_DX`c'=="Z21" | I10_DX`c'=="Z717"
replace hiv_aids=1 if I10_DX`c'=="Z830"
}
gen peptic_ulcer=0
forvalues c=1/25 {
replace peptic_ulcer=1 if I10_DX`c'=="K269" | I10_DX`c'=="K27" | I10_DX`c'=="K270" | I10_DX`c'=="K271"
replace peptic_ulcer=1 if I10_DX`c'=="K272" | I10_DX`c'=="K273" | I10_DX`c'=="K274" | I10_DX`c'=="K275"
replace peptic_ulcer=1 if I10_DX`c'=="K276" | I10_DX`c'=="K277" | I10_DX`c'=="K279" | I10_DX`c'=="K28"
replace peptic_ulcer=1 if I10_DX`c'=="K280" | I10_DX`c'=="K281" | I10_DX`c'=="K282" | I10_DX`c'=="K283"
replace peptic_ulcer=1 if I10_DX`c'=="K284" | I10_DX`c'=="K285" | I10_DX`c'=="K286" | I10_DX`c'=="K287"
replace peptic_ulcer=1 if I10_DX`c'=="K289"
}

tab peptic_ulcer
tab hiv_aids
```

```
tab paralysis
tab liver_disease
tab atrial_fibrillation
gen coagulopathy=0
forvalues c=1/25 {
replace coagulopathy=1 if I10_DX`c'=="D684" | I10_DX`c'=="D685" | I10_DX`c'=="D6851" | I10_DX`c'=="D6852"
replace coagulopathy=1 if I10_DX`c'=="D6859" | I10_DX`c'=="D686" | I10_DX`c'=="D6861" | I10_DX`c'=="D6862"
replace coagulopathy=1 if I10_DX`c'=="D6869" | I10_DX`c'=="D688" | I10_DX`c'=="D689" | I10_DX`c'=="D69"
replace coagulopathy=1 if I10_DX`c'=="D690" | I10_DX`c'=="D691" | I10_DX`c'=="D692" | I10_DX`c'=="D693"
replace coagulopathy=1 if I10_DX`c'=="D694" | I10_DX`c'=="D6941" | I10_DX`c'=="D6942" | I10_DX`c'=="D6949"
}
tab coagulopathy

gen dementia=0
forvalues c=1/25 {
replace dementia=1 if I10_DX`c'=="F02C" | I10_DX`c'=="F02C0" | I10_DX`c'=="F02C1" | I10_DX`c'=="F02C11"
replace dementia=1 if I10_DX`c'=="F02C18" | I10_DX`c'=="F02C2" | I10_DX`c'=="F02C3" | I10_DX`c'=="F02C4"
replace dementia=1 if I10_DX`c'=="F03" | I10_DX`c'=="F039" | I10_DX`c'=="F0390" | I10_DX`c'=="F0391"
replace dementia=1 if I10_DX`c'=="F03911" | I10_DX`c'=="F03918" | I10_DX`c'=="F0392" | I10_DX`c'=="F0393"
replace dementia=1 if I10_DX`c'=="F0394" | I10_DX`c'=="F03A" | I10_DX`c'=="F03A0" | I10_DX`c'=="F03A1"
replace dementia=1 if I10_DX`c'=="F03A11"
}

tab dementia
*****Charlson Comorbidity Index****
gen charlson_index = 0
replace charlson_index = charlson_index + 2 if heart_failure == 1
replace charlson_index = charlson_index + 2 if hyperlipidemia == 1
replace charlson_index = charlson_index + 2 if ischemic_cvd == 1
replace charlson_index = charlson_index + 1 if atrial_fibrillation == 1
replace charlson_index = charlson_index + 1 if dementia == 1
replace charlson_index = charlson_index + 1 if copd == 1
replace charlson_index = charlson_index + 1 if peptic_ulcer == 1
```

```
replace charlson_index = charlson_index + 1 if hypertension == 1
replace charlson_index = charlson_index + 2 if diabetes == 1
replace charlson_index = charlson_index + 1 if paralysis == 1
replace charlson_index = charlson_index + 2 if ckd == 1
replace charlson_index = charlson_index + 6 if solid_cancer == 1
replace charlson_index = charlson_index + 4 if liver_disease == 1
replace charlson_index = charlson_index + 6 if hiv_aids == 1
replace charlson_index = charlson_index + 1 if coagulopathy == 1
```

******* Classification******

```
gen grpci = .
replace grpci = 0 if charlson_index == 0
replace grpci = 1 if inrange(charlson_index , 1, 2)
replace grpci = 2 if charlson_index  >= 3
```

*********Table 1********

```
oneway AGE Quintile5Distressed, bonferroni tabulate
tabulate AGE2 Quintile5Distressed, cell chi2 column expected row
tabulate FEMALE Quintile5Distressed, cell chi2 column expected row
tabulate RACE4 Quintile5Distressed, cell chi2 column expected row
tabulate Insurance Quintile5Distressed, cell chi2 column expected row
tabulate grpci Quintile5Distressed, cell chi2 column expected row
tabulate Obesity_Class Quintile5Distressed, cell chi2 column expected row
tabulate Urban Quintile5Distressed, cell chi2 column expected row
```

*********Table 2**********

```
oneway AGE BS, bonferroni tabulate
tabulate AGE2 BS, cell chi2 column expected row
```

```
tabulate Quintile5Distressed BS, cell chi2 column expected row
tabulate RACE4 BS, cell chi2 column expected row
tabulate Insurance BS, cell chi2 column expected row
tabulate grpci BS, cell chi2 column expected row
tabulate FEMALE BS, cell chi2 column expected row
tabulate Obesity_Class BS, cell chi2 column expected row
tabulate Urban BS, cell chi2 column expected row


******Logistic Regression*****
*******Table 3*****
logit BS i.Quintile5Distressed i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban,or

***Interaction Term analysis****
***** Table 4 & Figure 1*****

logit BS i.Quintile5Distressed##i.RACE4 i.AGE2 FEMALE  i.Insurance grpci Obesity_Class i.Urban,or

*****margins****
margins, dydx(RACE4) at(Quintile5Distressed =(1 2 3 4 5)) post
marginsplot


******Sensitivity analysis*****
logit BS i.adi_category i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban,or
logit BS i.adi_category##i.RACE4 i.AGE2 FEMALE  i.Insurance grpci Obesity_Class i.Urban,or
margins, dydx(RACE4) at(adi_category=(1 2 3 4 5)) post
marginsplot
```

Appendix D: STATA ANALYTCI DATA FOR PAPER 2

Study II
Patient Selection

```
gen AcuteCholecystitis = 0
forvalues c=1/25 {
replace AcuteCholecystitis = 1 if I10_DX`c' == "K810" | I10_DX`c' == "K8000" | I10_DX`c' == "K8001"
replace AcuteCholecystitis = 1 if I10_DX`c' == "K812" | I10_DX`c' == "K9189" | I10_DX`c' == "T8189XA"
replace AcuteCholecystitis = 1 if I10_DX`c' == "T8189XD" | I10_DX`c' == "T8189XS"
}
gen GI_Leak = 0
forvalues c=1/25 {
replace GI_Leak = 1 if I10_DX`c' == "K9189" | I10_DX`c' == "T8131XA" | I10_DX`c' == "T8131XD"
replace GI_Leak = 1 if I10_DX`c' == "T8131XS" | I10_DX`c' == "K912" | I10_DX`c' == "K913"
replace GI_Leak = 1 if I10_DX`c' == "K914" | I10_DX`c' == "T8183XA" | I10_DX`c' == "T8183XD"
replace GI_Leak = 1 if I10_DX`c' == "T8183XS"
}

gen GI_Stenosis = 0
forvalues c=1/25 {
replace GI_Stenosis = 1 if I10_DX`c' == "K9581" | I10_DX`c' == "K318" | I10_DX`c' == "K914"
replace GI_Stenosis = 1 if I10_DX`c' == "K915" | I10_DX`c' == "T86890" | I10_DX`c' == "T86898"
replace GI_Stenosis = 1 if I10_DX`c' == "K228" | I10_DX`c' == "K220" | I10_DX`c' == "Q390"
}
gen GI_Bleeding = 0
forvalues c=1/25 {
replace GI_Bleeding = 1 if I10_DX`c' == "K9221" | I10_DX`c' == "K9222" | I10_DX`c' == "K920"
replace GI_Bleeding = 1 if I10_DX`c' == "K921" | I10_DX`c' == "K228" | I10_DX`c' == "K252"
replace GI_Bleeding = 1 if I10_DX`c' == "K254" | I10_DX`c' == "K256" | I10_DX`c' == "K262"
replace GI_Bleeding = 1 if I10_DX`c' == "K264" | I10_DX`c' == "K266" | I10_DX`c' == "K272"
replace GI_Bleeding = 1 if I10_DX`c' == "K274" | I10_DX`c' == "K276" | I10_DX`c' == "K282"
replace GI_Bleeding = 1 if I10_DX`c' == "K284" | I10_DX`c' == "K286" | I10_DX`c' == "I850"
replace GI_Bleeding = 1 if I10_DX`c' == "I982" | I10_DX`c' == "D683" | I10_DX`c' == "D6831"
```

```
replace GI_Bleeding = 1 if I10_DX`c' == "D684" | I10_DX`c' == "K312" | I10_DX`c' == "T8101XA"
replace GI_Bleeding = 1 if I10_DX`c' == "T8101XD" | I10_DX`c' == "T8101XS"
}
gen VTE1 = 0
forvalues c=1/25 {
replace VTE1 = 1 if I10_DX`c' == "I2601" | I10_DX`c' == "I2602" | I10_DX`c' == "I2609"
replace VTE1 = 1 if I10_DX`c' == "I2690" | I10_DX`c' == "I2699" | I10_DX`c' == "I801"
replace VTE1 = 1 if I10_DX`c' == "I802"  | I10_DX`c' == "I803" | I10_DX`c' == "I808"
replace VTE1 = 1 if I10_DX`c' == "I809" | I10_DX`c' == "I822" | I10_DX`c' == "I823"
replace VTE1 = 1 if I10_DX`c' == "I824" | I10_DX`c' == "I8240" | I10_DX`c' == "I8249"
replace VTE1 = 1 if I10_DX`c' == "I825" | I10_DX`c' == "I828" | I10_DX`c' == "I829"
replace VTE1 = 1 if I10_DX`c' == "O223" | I10_DX`c' == "O87" | I10_DX`c' == "O879"
replace VTE1 = 1 if I10_DX`c' == "Z86718" | I10_DX`c' == "T81718A" | I10_DX`c' == "T81718D"
replace VTE1 = 1 if I10_DX`c' == "T81718S"
}

gen Ulcers = 0
forvalues c=1/25 {
replace Ulcers = 1 if I10_DX`c' == "K250" | I10_DX`c' == "K251" | I10_DX`c' == "K252"
replace Ulcers = 1 if I10_DX`c' == "K253" | I10_DX`c' == "K254" | I10_DX`c' == "K255"
replace Ulcers = 1 if I10_DX`c' == "K256" | I10_DX`c' == "K257" | I10_DX`c' == "K259"
replace Ulcers = 1 if I10_DX`c' == "K260" | I10_DX`c' == "K261" | I10_DX`c' == "K262"
replace Ulcers = 1 if I10_DX`c' == "K263" | I10_DX`c' == "K264" | I10_DX`c' == "K265"
replace Ulcers = 1 if I10_DX`c' == "K266" | I10_DX`c' == "K267" | I10_DX`c' == "K269"
replace Ulcers = 1 if I10_DX`c' == "K270" | I10_DX`c' == "K271" | I10_DX`c' == "K272"
replace Ulcers = 1 if I10_DX`c' == "K273" | I10_DX`c' == "K274" | I10_DX`c' == "K275"
replace Ulcers = 1 if I10_DX`c' == "K276" | I10_DX`c' == "K277" | I10_DX`c' == "K279"
replace Ulcers = 1 if I10_DX`c' == "K280" | I10_DX`c' == "K281" | I10_DX`c' == "K282"
replace Ulcers = 1 if I10_DX`c' == "K283" | I10_DX`c' == "K284" | I10_DX`c' == "K285"
replace Ulcers = 1 if I10_DX`c' == "K286" | I10_DX`c' == "K287" | I10_DX`c' == "K289"
}

gen PouchStretch = 0
```

```
forvalues c=1/25 {
replace PouchStretch = 1 if I10_DX`c' == "K3184" | I10_DX`c' == "K3189" | I10_DX`c' == "K229"
replace PouchStretch = 1 if I10_DX`c' == "K220" | I10_DX`c' == "K221" | I10_DX`c' == "K228"
replace PouchStretch = 1 if I10_DX`c' == "K919" | I10_DX`c' == "K923" | I10_DX`c' == "K928"
}

gen PersistentVomitingPain = 0
forvalues c=1/25 {
replace PersistentVomitingPain = 1 if I10_DX`c' == "R1110" | I10_DX`c' == "R1111" | I10_DX`c' == "R1112"
replace PersistentVomitingPain = 1 if I10_DX`c' == "K3181" | I10_DX`c' == "K3182" | I10_DX`c' == "K3183"
replace PersistentVomitingPain = 1 if I10_DX`c' == "K919" | I10_DX`c' == "R1013" | I10_DX`c' == "R1014"
replace PersistentVomitingPain = 1 if I10_DX`c' == "R1084" | I10_DX`c' == "R1089" | I10_DX`c' == "K938"
}


*****Short-Term Post-Operative Complication****
gen complication_Index = 0
replace complication_Index = complication_Index + 1 if AcuteCholecystitis == 1
replace complication_Index = complication_Index + 1 if GI_Leak == 1
replace complication_Index = complication_Index + 1 if GI_Stenosis == 1
replace complication_Index = complication_Index + 1 if GI_Bleeding == 1
replace complication_Index = complication_Index + 1 if VTE1 == 1
replace complication_Index = complication_Index + 1 if Ulcers == 1
replace complication_Index = complication_Index + 1 if PouchStretch == 1
replace complication_Index = complication_Index + 1 if PersistentVomitingPain == 1
replace complication_Index = complication_Index + 1 if DIED == 1
```

*******Baseline Characteristics*******

```
oneway AGE CI if BS==1, bonferroni tabulate
tabulate AGE2 CI if BS==1, cell chi2 column expected row
tabulate Quintile5Distressed CI if BS==1, cell chi2 column expected row
tabulate RACE4 CI if BS==1, cell chi2 column expected row
tabulate Insurance CI if BS==1, cell chi2 column expected row
```

```
tabulate grpci CI if BS==1, cell chi2 column expected row
tabulate FEMALE CI if BS==1, cell chi2 column expected row
tabulate Obesity_Class CI if BS==1, cell chi2 column expected row
tabulate Urban CI if BS==1, cell chi2 column expected row
```

*******Table 2*****

```
tab CIb
tab VTE1
tab GI_Leak
tab GI_Bleeding
```

*******Logistic Regression*****

*******Table 3*****

```
logit CIb i.Quintile5Distressed i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit VTE1 i.Quintile5Distressed i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Leak i.Quintile5Distressed i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Bleeding i.Quintile5Distressed i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
```

*****Interaction Term analysis****

******Table 4*****

```
logit CIb i.Quintile5Distressed##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit VTE1 i.Quintile5Distressed##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Leak i.Quintile5Distressed##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Bleeding i.Quintile5Distressed##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
```

****margins******

```
margins, dydx(RACE4) at(Quintile5Distressed =(1 2 3 4 5)) post
marginsplot
```

********Sensitivity analysis*******

```
logit CIb i.adi_category i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit VTE1 i.adi_category i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Leak i.adi_category i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Bleeding i.adi_category i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
```

********Interaction Term analysis******

```
logit CIb i.adi_category ##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit VTE1 i.adi_category ##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Leak i.adi_category ##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Bleeding i.adi_category ##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
```

******margins******

```
margins, dydx(RACE4) at(adi_category=(1 2 3 4 5)) post
marginsplot
```

Appendix E: STATA ANALYTICAL DATA FOR PAPER 3

Study III

Table 1

*********Baseline Characteristics****

```
oneway AGE Quintile5Distressed if BS==1, bonferroni tabulate
tabulate AGE2 Quintile5Distressed if BS==1, cell chi2 column expected row
tabulate FEMALE Quintile5Distressed if BS==1, cell chi2 column expected row
tabulate RACE4 Quintile5Distressed if BS==1, cell chi2 column expected row
tabulate Insurance Quintile5Distressed if BS==1, cell chi2 column expected row
tabulate grpci Quintile5Distressed if BS==1, cell chi2 column expected row
tabulate Obesity_Class Quintile5Distressed if BS==1, cell chi2 column expected row
tabulate Urban Quintile5Distressed if BS==1, cell chi2 column expected row
```

*******Univariate analysis: Outcomes****

*****Table 2*****

```
tabulate READMIT Quintile5Distressed if BS==1, cell chi2 column expected row
```

*****Table 3*****

```
oneway LOS Quintile5Distressed if BS==1, bonferroni tabulate
```

*******Table 4******

```
logit READMIT i.Quintile5Distressed i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
```

*******Table 5******

```
regress LOS i.Quintile5Distressed i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1
```

******Interaction Term analysis******

********Table 6*****

```
regress LOS i.Quintile5Distressed##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1
```

**********Table 7********

```
logit READMIT i.Quintile5Distressed##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
```

******margins********

```
margins, dydx(RACE4) at(Quintile5Distressed =(1 2 3 4 5)) post
marginsplot
```

********Sensitivity analysis*******

```
logit READMIT i.adi_category i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1,or
regress LOS i.adi_category i.AGE2 FEMALE i.RACE4 i.Insurance grpci Obesity_Class i.Urban if BS==1
```

*****Interaction Term analysis******

```
logit CIb i.adi_category ##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit VTE1 i.adi_category ##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Leak i.adi_category ##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
logit GI_Bleeding i.adi_category ##i.RACE4 i.AGE2 FEMALE i.Insurance grpci Obesity_Class i.Urban if BS==1,or
```

******margins******

```
margins, dydx(RACE4) at(adi_category=(1 2 3 4 5)) post
marginsplot
```

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