Distribution Agreement

In presenting this thesis or dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

______________________________ _______________

Radhika Agarwal Date

Odds of 30-Day All-Cause Hospital Readmissions after Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity in Georgia, 2017

By:

Radhika Agarwal
Degree to be awarded: MPH

Executive MPH

____

Mohammed K. Ali, MD, MSc, MBA
Committee Chair

____

Sara Turbow, MD, MPH
Committee Member

Odds of 30-Day All-Cause Hospital Readmissions after Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity in Georgia, 2017

By:

Radhika Agarwal
M.D., Loyola University Chicago Stritch School of Medicine, 2019
M.A., Loyola University Chicago, 2014
B.A., Northwestern University, 2013

Thesis Committee Chair: Mohammed K. Ali, MD, MSc, MBA

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Applied Epidemiology
2024

Abstract

Odds of 30-Day All-Cause Hospital Readmissions after Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity in Georgia, 2017

By Radhika Agarwal

Background

Diabetic lower extremity ulcers (DLEU) are associated with significant healthcare utilization, including 30-day readmissions. Two previous studies have found no difference in 30-day readmissions after an index admission for DLEU by race and ethnicity for two small cohorts, while an administrative database analyses from New York and Florida found increased adjusted odds of 30-day all-cause readmission in Black and Hispanic people with DLEU. There is limited literature about 30-day readmissions related to DLEU in Georgia, a state along the "diabetes belt". In our analysis, we examine the odds of 30-day all-cause readmissions after an admission for DLEU by race and ethnicity in Georgia in 2017.

Methods

We conducted a retrospective database analysis of the 2017 Georgia State Inpatient Database from the Agency for Healthcare Research and Quality. Individuals can be followed over the year in this database. We identified admissions with a diagnosis of DLEU at any position based on ICD-10 codes. Using unadjusted and adjusted logistic regression, we examined the odds of all-cause 30-day readmission following an initial admission for DLEU by race and ethnicity.

Results

23,209 hospitalizations for DLEU were analyzed. 5,106 (22.0%) claims had all-cause readmissions within 30 days. 56% of the claims were from White patients, 38% from Black patients, 4% from Hispanic patients, 1% from Asian or Pacific Islander patients, and 2% from Native American or Other race and ethnicity patients. The unadjusted odds for all-cause 30-day readmission were higher in Black patients compared to White patients (OR 1.20, 95% CI 1.13, 1.27) and lower in Native American/Other patients compared to White patients (OR 0.78, 95% CI 0.61, 0.99). However, after adjusting for individual and hospital-level covariates, there was no difference in odds of all-cause 30-day readmission by race and ethnicity.

Conclusion

In this study, individual-level and hospital-level covariates accounted for differences in all-cause 30-day readmissions after initial admission for DLEU by race and ethnicity. These factors reflect social and structural determinants of health, for which race and ethnicity often serves as a proxy. Capturing data related to social and structural determinants of health in datasets can help identify more accurate contributors to disparities.

Odds of 30-Day All-Cause Hospital Readmissions after Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity in Georgia, 2017

By:

Radhika Agarwal
M.D., Loyola University Chicago Stritch School of Medicine, 2019
M.A., Loyola University Chicago, 2014
B.A., Northwestern University, 2013

Thesis Committee Chair: Mohammed K. Ali, MD, MSc, MBA

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Applied Epidemiology
2024

Acknowledgements

Thank you to Dr. Sara Turbow, Dr. Mohamed K. Ali, Emory University's Preventive Medicine Residency program, and Emory University's Executive Master of Public Health program for their guidance and support.

Table of Contents

Chapter 1: Literature Review

Introduction

Diabetic lower extremity ulcers (DLEU) are wounds of the lower extremities of diabetic patients and are associated with significant healthcare utilization. In 2021, there were 38.4 million people with diabetes in the United States[1]. It is estimated that 13% of people with diabetes have lower extremity ulcers[2], corresponding to 5 million individuals in the United States. Management of DLEU can be resource-intensive, requiring access to healthcare, wound management services, and social support. Complications of these ulcers include recurrence, infection, amputation, and mortality. As a result, there is a high burden of hospital admissions and readmissions. DLEU are also disproportionately prevalent by race and ethnicity in the US. This thesis examines 30-day readmissions after an initial admission for DLEU by race and ethnicity in Georgia in 2017.

This literature review will provide a brief overview of DLEU, its epidemiology, hospital utilization, and disparities by race and ethnicity in the United States and in Georgia.

Overview of Diabetic Lower Extremity Ulcers

Diabetes mellitus (DM) is a disease characterized by elevated glucose levels in the blood. Uncontrolled diabetes is associated with nerve damage (neuropathy) and damage to the inner lining of blood vessels leading to improper blood flow (vascular insufficiency).[3] Nerve damage commonly affects the feet, affecting the ability to sense pain or pressure, thereby leading to injury and wound formation. Improper blood flow to an area is associated with impaired healing from injuries. Wounds can become infected and if infection extends beyond the skin into the bone, they can cause osteomyelitis. In cases of progressive osteomyelitis, amputation is performed to remove the infected portion of the limb and preserve the healthy portion of the limb. In addition to neuropathy and vascular disease, risk factors for diabetic foot disease include foot deformity, previous foot ulceration, age, sex (more prevalent in men than women), race and ethnicity, socioeconomic status, level of diabetes control, weight, smoking, cardiovascular disease, chronic kidney disease, and diabetic retinopathy.[3]

Epidemiology of Diabetic Lower Extremity Ulcers in the United States and Georgia

In the United States, an estimated 38.4 million people had type 1 or type 2 DM in 2021.[1] Because no surveillance system exists for DLEU in the United States, estimates for prevalence and incidence are variable. A 2017 systematic review by Zhang et al. estimated the prevalence of DLEU to be 13% of all people with diabetes in the United States[2], which would translate to 5 million Americans in 2021. Around the world, incidence estimates range from 0.1% to 8% of people with diabetes in population-based studies[3] which would translate from 38,400 to around 3.1 million Americans per year. The lifetime risk of developing a DLEU is 12-34% among people with diabetes.[3] Approximately 50% of DLEU become infected.[4] Of those with infected DLEU, 15-20% will require amputation.[4] A 2023 systematic review of DLEU-related mortality by Chen et al. found that 5 and 10-year mortality rates following the development of DLEU are high: 49.1% and 78.9%, respectively.[5]

In the state of Georgia, approximately 12.4% of residents (around 1 million people) have diabetes.[6] There are no estimates for prevalence, incidence, amputation, and mortality related to

DLEU specific to Georgia in the literature. If we were to apply global prevalence estimates to the Georgia population, the prevalence of DLEU would be around 130,000 people.

Race/Ethnicity and Diabetic Lower Extremity Ulcers in the United States and Georgia

The prevalence of diabetes in the United States varies by race and ethnicity. For the following literature review, we will refer to racial and ethnic groups as named by the authors. In 2021, 13.6% of American Indians/Alaskan Native adults, 12.1% of non-Hispanic Black adults, 11.7% of Hispanic adults, 9.1% of Asian American adults, and 6.9% of non-Hispanic White adults had diabetes.[7] While overall prevalence of DLEU by race and ethnicity is not known for the entire United States, in an Agency for Healthcare Research and Quality (AHRQ) analysis of Medicare fee-for-service beneficiaries in 2007, the prevalence of DLEU was found to be 8.0% for White diabetic patients, 8.7% for African American diabetic patients, 4.2% for Asian diabetic patients, 8.6% for Hispanic diabetic patients, and 9.6% for American Indian/Alaska Native diabetic patients.[8] In the same AHRQ analysis, for 2007, the incidence of DLEU was 6.0-6.8% for all racial groups except for Asian patients who had an incidence of 3.4%.

Racial/ethnic disparities in amputation have also been studied. In the same AHRQ analysis in 2007, prevalence of amputation was 1.5% for non-Hispanic White patients, 3.3% for African American patients, 0.7% for Asian patients, 2.6% for Hispanic patients, and 3.8% for American Indian/Alaska Native patients.[8] In a more recent analysis of 124,487 Medicare beneficiaries hospitalized with DLEU in 2013 and 2014, 21.9% of patients who identified as Black had major amputation or death during index admission or within 30 days of index admission, compared to 18.3% of patients who identified as Hispanic, 16.5% of patients who identified as White, and

18.2% of patients who identified as another race or ethnicity.[9] In an analysis of 68,633 Medicare fee-for-service beneficiaries from 2012 – 2017, Miller et al. found that Black/African American beneficiaries had 1.98 (95% CI 1.93–2.03) times the odds of receiving a lower extremity amputation within 1 year of DLEU diagnosis compared with non-Hispanic White beneficiaries, suggesting that non-Black beneficiaries may have better access to conservative wound management resources, among other contributing factors.[10] Similarly, Tan et al. showed that in a population of 92,929 Medicare beneficiaries with newly diagnosed DLEU from 2011-2015, the risk of major amputation was significantly higher in African American patients (adjusted hazard ratio [aHR] =1.9, 95% CI 1.7 to 2.2) and Native American patients (aHR=1.8, 95% CI 1.3 to 2.6, p=0.001) compared to White patients.[11]

While literature on DLEU prevalence by race and ethnicity in Georgia was not found, there are differences in the prevalence of diabetes by race and ethnicity in the state. Per the 2020 Diabetes Action Plan by the Georgia Department of Public Health, non-Hispanic White individuals (12.0%) were more likely to have diagnosed diabetes compared to non-Hispanic Black (11.5%), Other (10.6%), and Hispanic (6.7%) individuals in 2017.[12] While these figures were obtained from the Behavioral Risk Factor Surveillance System (BRFSS) data, they appear to be a report of crude prevalence by race.[13] The CDC's United States Diabetes Surveillance System dashboard reports BRFSS data and displays both crude and age-adjusted rates.[13] In 2017, the age-adjusted prevalence of diabetes was 12.2% in Black adults, 10.0% in White adults, and 10.7% in Hispanic adults in Georgia.[13] These disparities have widened further as of 2021, with 15.1% of Black adults who have diabetes compared to 9.5% of White adults and 10.4% of Hispanic adults.[13]

Healthcare Utilization for Diabetic Lower Extremity Ulcers

Patients with DLEU have higher utilization of healthcare services. Rice et al. conducted a matched analysis of DLEU patients and control patients with Medicare or private insurance from a single payer from 2007-2010.[14] In the Medicare group, DLEU patients utilized 2.5 inpatient days after an initial encounter for DLEU compared to 1.1 for diabetic patients without DLEU ($p < 0.0001$).[14] In the privately insured group, DLEU patients utilized 19.5 inpatient days after an initial encounter for DLEU compared to 7.1 for diabetic patients without DLEU ($p < 0.0001$).[14] Additionally, in the Medicare group, DLEU patients had 59.6 outpatient/physician days (i.e. clinic visits) compared to 44.1 outpatient/physician days for patients without DLEU ($p < 0.0001$).[14] In the privately insured group, DLEU patients had 20.2 outpatient days compared to 14.2 outpatient days for patients without DLEU ($p < 0.0001$).[14]

These numbers differ slightly from an AHRQ analysis of healthcare utilization for DLEU from 2006-2008.[15] AHRQ reported that Medicare fee-for-service beneficiaries with a DLEU were seen by their outpatient health care provider about 14 times per year and hospitalized about 1.5 times per year.[15] Utilization remained high after amputation in the AHRQ analysis: beneficiaries with a lower extremity amputation were seen by their outpatient health care provider about 12 times per year and hospitalized about 2 times per year.[15]

Among Medicare patients with DLEU in the AHRQ analysis, healthcare utilization varied by race and ethnicity. The mean number of all-cause admissions for White beneficiaries in 2007 was 1.33, compared to 1.86 admissions for Black beneficiaries, 1.63 admissions for Hispanic beneficiaries, 1.69 admissions for North American Native beneficiaries, and 1.24 for Asian beneficiaries. *p*-values were not provided in this analysis. Interestingly, the mean number of office visits for White beneficiaries in 2007 was 14.04, compared to 11.20 visits for Black beneficiaries, 13.57 visits for Hispanic beneficiaries, 18.20 visits for North American Native beneficiaries, and 14.27 visits for Asian beneficiaries.

30-Day Readmissions for Diabetic Lower Extremity Ulcers

30-day readmissions are unplanned hospital or observation admissions within 30 days of an index admission.[16] They are often avoidable and associated with adverse patient outcomes and higher costs.[16] Readmissions can be associated with social and structural inequities such as lack of insurance, education, income, lack of access to stable housing and food, and lack of social support, among others.[17] These inequities are often reflected in racial disparities of health outcomes as racial and ethnic minority groups face unequal distribution of resources and power.[17]

For some conditions, a readmission within 30 days will may not be fully reimbursed by the payor, and thus the provider or health system bears some of the cost. For Medicare patients, the Hospital Readmissions Reduction Program has been active since Oct 1, 2012 and states that 30-day readmissions for the following will incur reduced payments: acute myocardial infarction, chronic obstructive pulmonary disease, heart failure, pneumonia, coronary artery bypass graft surgery, and elective total hip or knee arthroplasty surgeries.[18] While diabetes and its complications are not yet on this list, 30-day readmissions can serve as a marker of severity of disease, unmet social needs, incomplete medical care, or lesser quality of care. We will thus look at odds of 30-day readmissions as an outcome in the following analysis.

The rate of 30-day readmissions or return to care associated with DLEU is high. In a cohort study of 206 patients by Holscher et al., there was a 17% unplanned all-cause 30-day readmission rate for patients with DLEU.[19] In a study of 25,911 discharges for DLEU in Florida and New York from 2011-2012 by Remington et al., the rate of return to care to inpatient or emergency department (ED) settings was 30%.[20] In comparison, the 30-day readmission rate for chronic obstructive pulmonary disease, one of the top 5 causes of 30-day readmissions in Medicare patients, is around 20%.[21]

When assessing 30-day readmissions following an admission for DLEU by race and ethnicity, data is mixed. Myers et al. conducted a retrospective chart review of 397 patients with DLEU from 2014-2018 and found that unadjusted race and ethnicity was not associated with an increased odds of 30-day readmission at a hospital in New York.[22] In the cohort study of 206 patient by Holscher et al., unadjusted race and ethnicity was not associated with unplanned 30-day readmission.[19] In the study of 25,911 discharges in Florida and New York from 2011-2012 by Remington et al., 30-day all-cause readmission to inpatient or ED setting was found to be associated with Black race (OR: 1.21, 95% CI 1.13, 1.29) and Hispanic ethnicity (OR 1.11, 95% CI 1.03, 1.21).[20]

Conclusion and Implications

This literature review provides an overview of the epidemiology DLEU, the association of DLEU with high utilization of healthcare services, and the disparities in healthcare utilization for DLEU by race and ethnicity in the United States. There is limited epidemiological data about DLEU for the state of Georgia. However, given the high burden of diabetes and racial/ethnic disparities in Georgia, there is a need to better assess the consequences of diabetes by race and ethnicity, including DLEU, and its association with healthcare utilization in Georgia. This thesis will examine odds of 30-day readmission after an initial admission for DLEU by race and ethnicity in Georgia in 2017. This analysis will provide information regarding hospital utilization for DLEU in Georgia and of potential disparities by race and ethnicity or by other individual or hospital-level covariates. Identified areas of disparities may inform further analysis and/or interventions to address health equity in management of DLEU.

Chapter 2: Manuscript

Odds of 30-Day All-Cause Hospital Readmissions after Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity in Georgia, 2017

Abstract

Background

Diabetic lower extremity ulcers (DLEU) are associated with significant healthcare utilization, including 30-day readmissions. Two previous studies have found no difference in 30-day readmissions after an index admission for DLEU by race and ethnicity for two small cohorts, while an administrative database analyses from New York and Florida found increased adjusted odds of 30-day all-cause readmission in Black and Hispanic people with DLEU. There is limited literature about 30-day readmissions related to DLEU in Georgia, a state along the "diabetes belt". In our analysis, we examine the odds of 30-day all-cause readmissions after an admission for DLEU by race and ethnicity in Georgia in 2017.

Methods

We conducted a retrospective database analysis of the 2017 Georgia State Inpatient Database from the Agency for Healthcare Research and Quality. Individuals can be followed over the year in this database. We identified admissions with a diagnosis of DLEU at any position based on ICD-10 codes. Using unadjusted and adjusted logistic regression, we examined the odds of all-cause 30-day readmission following an initial admission for DLEU by race and ethnicity.

Results

23,209 hospitalizations for DLEU were analyzed. 5,106 (22.0%) claims had all-cause readmissions within 30 days. 56% of the claims were from White patients, 38% from Black

patients, 4% from Hispanic patients, 1% from Asian or Pacific Islander patients, and 2% from Native American or Other race and ethnicity patients. The unadjusted odds for all-cause 30-day readmission were higher in Black patients compared to White patients (OR 1.20, 95% CI 1.13, 1.27) and lower in Native American/Other patients compared to White patients (OR 0.78, 95% CI 0.61, 0.99). However, after adjusting for individual and hospital-level covariates, there was no difference in odds of all-cause 30-day readmission by race and ethnicity.

Conclusion

In this study, individual-level and hospital-level covariates accounted for differences in all-cause 30-day readmissions after initial admission for DLEU by race and ethnicity. These factors reflect social and structural determinants of health, for which race and ethnicity often serves as a proxy. Capturing data related to social and structural determinants of health in datasets can help identify more accurate contributors to disparities.

Introduction

Diabetic lower extremity ulcers (DLEU) are wounds of the legs and feet of diabetic patients and are associated with significant healthcare utilization. Diabetes is one of the leading causes of non-traumatic amputation, with DLEU preceding approximately 80% of diabetes-related lower extremity amputations.[24] In 2021, there were 38.4 million people with diabetes in the United States [1] and around 1 million people with diabetes in Georgia.[12] It was estimated that 13% of people with diabetes have lower extremity ulcers[2], corresponding to about 5 million Americans and 130,000 Georgians. Risk factors for DLEU include diabetic neuropathy (nerve damage), diabetic vasculopathy (decreased blood flow), foot deformity, previous foot ulceration, age, sex (more prevalent in men than women), race and ethnicity, ethnicity, socioeconomic status, level of diabetes control, weight, smoking, cardiovascular disease, chronic kidney disease, and diabetic retinopathy.[3] Complications of DLEU include recurrence, infection, amputation, and mortality. Management of DLEU is often resource-intensive, requiring timely access to healthcare, inpatient and outpatient wound and diabetes management, and social support.

Prevalence of diabetes, DLEU, and diabetic amputation vary by race and ethnicity, with Black, Hispanic, and American Indian/Alaskan Native groups having higher rates than White groups in the United States.[7,8] The largest national analysis of DLEU prevalence, incidence, and cost was conducted by the Agency for Healthcare Research and Quality, using 2006-2008 claims data from Medicare Part A and B fee for service beneficiaries.[8] In this analysis, the prevalence of DLEU was found to be 8.0% for White diabetic patients, 8.7% for African American diabetic patients, 4.2% for Asian diabetic patients, 8.6% for Hispanic diabetic patients, and 9.6% for American Indian/Alaska Native diabetic patients in 2007.[8] Average annual costs also varied by race and ethnicity: White beneficiaries with DLEU had lower average annual reimbursement $30,100 in 2007 compared to African Americans at $47,200, Hispanics at $43,500, American Indian/Alaska Natives at $37,300, and Asian Americans at $37,700.[15]

Furthermore, the rate of 30-day readmissions or return to care associated with DLEU is high. In a cohort study of 206 patients by Holscher et al., there was a 17% unplanned all-cause 30-day readmission rate for patients with DLEU.[19] In a study of 25,911 discharges for DLEU in Florida and New York from 2011-2012 by Remington et al., the rate of return to care to inpatient or emergency department (ED) settings was 30%.[20] However, data is mixed when assessing 30-day readmissions after admission for DLEU by race and ethnicity. Two single-center studies of 397 and 206 patients, respectively, did not find higher odds of 30-day readmission by race and ethnicity.[19,22] In contrast, in the study of 25,911 discharges for DLEU in Florida and New York from 2011-2012 by Remington et al., 30-day all-cause readmission to inpatient or ED setting was found to be associated with Black race and ethnicity (OR: 1.21, 95% CI 1.13, 1.29) and Hispanic race and ethnicity (OR 1.11, 95% CI 1.03, 1.21).[20]

Georgia represents a portion of the "diabetes belt", where 111 of its 159 counties had a prevalence of diabetes of 11% or more according to 2007 and 2008 Behavioral Risk Factor Surveillance System data.[25] While literature is limited related to DLEU and health utilization in Georgia, there are racial differences in all-cause preventable hospitalizations in Georgia. According to 2020 data from the National Institute on Minority Health and Health Disparities, among patients aged 65 and older, White patients had preventable hospitalizations at a rate of 3,058 per 100,000 compared to Black patients with a rate of 4,401 per 100,000 in Georgia. To assess differences in hospitalization utilization by race as related to DLEU, we will examine the odds of all-cause 30-day readmissions after an initial admission for DLEU by race and ethnicity in Georgia in 2017.

Methods

Data source

The State Inpatient Databases (SID), are administrative databases of state-wide, all-payer hospital discharge data sponsored by the Healthcare Cost and Utilization Project (HCUP), part of the Agency for Healthcare Research and Quality.[26] Specific to each state, the SID includes de-identified clinical and healthcare-use information from inpatient discharge records each year, including principal and secondary diagnoses and procedures, demographic characteristics, length of stay, expected payment source, and payment charges.[26] We chose to analyze the Georgia SID from 2017 as it is the most comprehensive database of hospitalizations across the state, includes all payers and uninsured individuals, is standardized by HCUP, and contains hospitalization data for the entire year to follow readmissions. We also chose to study a time period prior to the Covid-19 pandemic to understand inpatient service use prior to changes in health behavior as a result of the pandemic. This dataset was available to our department through previous research and we obtained permission from HCUP to re-use it for this analysis.

The 2017 Georgia SID covers 136 of 141 hospitals and 98.8% of all discharges in the state. [27] Hospitals excluded from the SID include federal hospitals (such as the Veterans Affairs and Indian Health Service hospitals), hospitals within institutions such as prisons, psychiatric hospitals, and alcohol or chemical dependency treatment facilities.

Hospital-level covariates, such as bed size and teaching status, were obtained from the American Hospital Association's (AHA) linkage file which collects data through the AHA Annual Survey of Hospitals. We obtained this linkage file from the Georgia Hospital Association and merged it with the 2017 Georgia SID file using the AHA ID, which is a hospital identifier number available with each claim record.

HCUP standardizes data and variable names prior to releasing the dataset to researchers. Diagnoses are coded as per the *International Classification of Diseases, 10th Edition*.[28] As this was a retrospective analysis of de-identified data, IRB approval was not required. The Georgia SID contains a visit linkage variable, which is a non-identifying person number that allows tracking of a patient within the dataset to identify readmissions.

Study Population

We identified admissions with an ICD-10 code for type 1 or type 2 diabetes plus an ICD-10 for a diagnosis of lower extremity ulcer. We used ICD-10 code families E10.XX and E11.XX to identify patients with type 1 or type 2 diabetes, respectively. For DLEU, we used a set of 304 ICD-10 codes identified for administrative claims analyses by Fowler et al.[29] Admissions with DLEU were defined as the presence of the lower extremity ulcer code and diabetes code at any diagnosis position. These code classification for DLEU incorporates the following eight pathologies, as defined by Fowler et al.: cellulitis, cutaneous abscess, gangrene, lymphadenitis, non-pressure ulcers, onychia of toe, osteomyelitis, and pressure ulcer.[29] We excluded admissions which did not have the visit linkage variable, which is a non-identifying, unique person number that allows tracking of a patient within the dataset to identify readmissions. Readmissions were not limited by diagnosis.

Study Design

This is a cross-sectional analysis of admissions for DLEU in the 2017 Georgia SID. A primary analysis and three sensitivity analyses were completed.

Outcomes and Exposures

Our primary outcome was the odds ratio of a 30-day readmission for any reason after an index admission for DLEU. Every admission coded for a DLEU was considered. Our main exposure was reported race and ethnicity categorized as follows: White, Black, Hispanic, Asian or Pacific Islander, and Native American/Other. The Native American and Other groups were combined due to low counts.

Covariates

We identified individual-level and hospital-level covariates to consider in the analysis. Individual-level covariates included age in years, sex, quartile of median household income in the individual's zip code, Elixhauser 30-day readmission index, primary expected payer, admission length of stay, rural-urban county classification of patient's location, and social vulnerability index (SVI) by patient's county. Age was coded as integer values until age 89, after which age is grouped as 90+.[30] Sex was categorized as male or female.[30] The median household income of the individual's zip code was ranked into quartiles from poorest to wealthiest defined by the following ranges: quartile 1 as $1 - $43,999, quartile 2 as $44,000 - $55,999, quartile 3 as $56,000 - $73,999, and quartile 4 as 74,000+.[30]

The Elixhauser 30-day readmission index was obtained through the Elixhauser Comorbidity Software Refined for ICD-10-CM developed as part of HCUP.[31] It assesses for 38 pre-existing conditions from secondary diagnoses which impact health resource use and is a composite score which ranges from -2 to 54.[32] This served as a measure of comorbidity burden for the individual.

The primary expected payor was recategorized to 4 groups: Medicare, Medicaid, private insurance, and a combined group of self-pay, other, no charge, and missing. [30] Admission length of stay was represented in integer number of days. [30] Based on the Rural-Urban Continuum Codes (RUCC) developed by the U.S. Department of Agriculture, rural-urban county classification of patient's location was recategorized into three groups: metropolitan area (RUCC 1-3), nonmetropolitan area adjacent to a metropolitan area (RUCC 4, 6, 8), and nonmetropolitan area not adjacent to a metropolitan area (RUCC 5, 7, 9). [30]

The social vulnerability index was developed by the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry in 2007 to identify vulnerable communities for disaster management purposes, but has been widely adopted as a proxy for social determinants of health in health services research.[33-35] It uses percentile ranks of 16 variables from the 5-year American Community Survey in the following domains: housing type and transportation, household characteristics, racial & ethnic minority status, and socioeconomic status. [33] The final ranking ranges from 0 to 1 as least to greatest vulnerability respectively. [33] To obtain the patient's SVI by their county of residence, we used the 2016 county-level SVI dataset to merge SVI scores to the county FIPS code of the individual.

Hospital-level covariates obtained from the AHA Linkage file include hospital bed size, hospital ownership, teaching status, and metropolitan statistical area designation. Hospital bed size was recategorized into 4 groups: 6-99 beds, 100-299 beds, 300-499 beds, and 500+ beds. Hospital ownership was recategorized into 4 groups: regional (county, city-county, hospital district or authority), church operated, not-for-profit, or private (individual, partnership, corporation). Teaching hospitals were defined as fulfilling any of the following 3 variables: participating site recognized for one or more Accreditation Council for Graduate Medical Education accredited programs, medical school affiliation reported to the American Medical Association (AMA), or member of the Council of Teaching Hospitals (COTH) of the Association of American Medical Colleges. The hospital's rural-urban categorization was defined by the Core-Based Statistical Area Type developed by U.S. Census Bureau and categorized as metropolitan, micropolitan, or rural.

Statistical Analysis

Descriptive analyses were used to compare individual-level and hospital-level variables across categories of race and ethnicity. Chi-square and one-way ANOVA tests were used to analyze the statistical significance of categorical and numerical variables, respectively. Unadjusted logistic regression for each individual-level and hospital-level characteristic was conducted. Multicollinearity was assessed via conditional indices (CNI) and variance decomposition proportions with CNI values >30 indicating the presence of multicollinearity. Multivariate logistic regression was conducted for three models: individual-level covariates only, hospital-level covariates only, and for all covariates. Each regression utilized forward stepwise selection significance level for entry at 0.20 and backwards elimination with significance level for staying at 0.05. Odds ratios and confidence limits were used as measures of association. $P < 0.05$ was considered statistically significant.

We conducted three sensitivity analyses. The first analysis assessed odds ratios of all-cause readmission within 90-days and within the entire year of 2017 after an admission for DLEU. The second analysis assessed odds ratios of 30-day readmission for a diagnosis of DLEU at any position, instead of all-cause readmissions, after initial admission for DLEU. The third analysis assessed odds of all-cause 30-day readmissions by race and ethnicity after an initial admission for a major lower extremity amputation. Major lower extremity amputations were identified by ICD-10 codes previously used by Lobo et al.[36] All statistical analyses were completed using SAS statistical software, version 9.4 (SAS Institute, Cary NC).[37]

Results

The Georgia SID had 1,089,399 claims in 2017 (Figure 1). Of this, 1,088,904 claims had the linkage variable present and 495 were excluded. 23,328 had an admission with a diagnosis of DLEU at any position. Out of this, 23,209 claims had data for race and ethnicity. This formed our study population. 11,460 (49.4%) claims had readmission for any cause in 2017 and 5,106 (22.0%) claims had all-cause readmissions within 30 days.

Individual-level and hospital-level characteristics by race and ethnicity are presented in Table 1. Of the 23,209 claims with a diagnosis of DLEU at any position, 56% represented White individuals, 38% represented Black individuals, 4% represented Hispanic individuals, 1%

represented Asian or Pacific Islander individuals, and 2% represented Native American or Other individuals. These proportions were similar for all-cause 30-day readmissions.

White individuals had the oldest mean age at 63.84 years while Black and Hispanic individuals had the youngest mean ages at 60.75 years and 58.93 years respectively ($p < 0.001$). The proportion of female patients who were Black (43%) was higher than the proportion of male patients who were Black (36%) ($p < 0.001$). White individuals represented 75% of claims from individuals who live in counties with the highest quartile of median household income, whereas Black individuals represented 19% ($p < 0.001$). In contrast, White individuals represented 46% of claims from individuals who live in counties with the lower quartile of median household income, compared to 49% of Black individuals ($p < 0.001$). Black individuals had the highest median Elixhauzer 30-day readmission index at 14 (IQR 7-21) and Native American/Other individuals had the lowest at 9 (IQR 4-17) ($p < 0.001$).

The average length of stay was 8.09 (SD 8.78) days for White individuals, 9.87 (SD 11.16) days for Black individuals, 7.48 (SD 6.06) days for Hispanic individuals, 10.61 (SD 11.73) days for Asian or Pacific Islander individuals, and 10.81 (SD 17.96) days for Native American/Other individuals ($p < 0.001$). The median social vulnerability index was higher for Hispanic patients (0.51, IQR 0.21-0.58) and Black patients (0.45, IQR 0.28-0.73) when compared to White patients (0.34, IQR 0.15-0.61) ($p < 0.001$). Relative to their proportion in the study population (36%), Black patients were notably overrepresented in the Medicaid payor group (48%) ($p < 0.001$). White patients were overrepresented in the private payor group at 62% ($p < 0.001$). In terms of rurality of patient's county, 66% of claims from nonmetropolitan areas not adjacent to metropolitan areas were from White patients compared to 30% from Black patients ($p < 0.001$).

Relative to their proportion in the sample, claims from White patients were higher from regional-owned (65%) and church-owned (66%) hospitals whereas for Black patients, claims from not-for-profit institutions were greater (40%) ($p < 0.001$). Additionally, relative to their proportion in the sample, claims for Black patients were greater at teaching hospitals (45%) ($p < 0.001$). White patients were overrepresented in rural hospitals (72%) compared to Black patients (27%) ($p < 0.001$).

Regression

There was no multicollinearity present among the covariates. In the unadjusted model, compared to non-Hispanic Whites, non-Hispanic Blacks had 20% higher odds of all-cause 30-day readmission (OR 1.20, 95% CI 1.13, 1.27) (Table 2). The Native American/Other race category was associated with 22% lower odds of all-cause 30-day readmission (OR 0.78, 95% CI 0.61, 0.99) compared to the White race category. After adjustment with individual-level covariates in model 1, there were no differences in odds of readmission by race and ethnicity (Table 2). After adjustment with only hospital-level covariates in model 2, Black race and ethnicity was associated with 17% higher odds of all-cause 30-day readmission (AOR 1.17, 95% CI 1.10, 1.25) compared to White race. Hispanic ethnicity and Native American/Other race and ethnicity were associated with 16% and 22% lower odds, respectively, of all-cause 30-day readmission (AOR 0.84, 95% CI 0.71, 0.99 and AOR 0.78, 95% CI 0.61, 0.99) respectively (Table 2). In the final adjusted model including both individual-level and hospital-level variables, there were no differences in odds of readmission by race and ethnicity. Covariates in the final model included:

age, Elixhauser 30-day readmission index, payer, length of stay of index admission, patient's rural urban county classification, hospital bed size, hospital teaching status, and hospital metropolitan statistical area classification (Table 3 and Figure 4).

Sensitivity Analysis

There were no significant differences by race and ethnicity for 90-day all-cause readmission after admission for DLEU. For same year readmissions (within 2017), Hispanic patients and Native American/Other patients had lower odds of readmission compared to White patients (AOR 0.79, 95% CI 0.67, 0.92 and AOR 0.72, 95% CI 0.58, 0.89 respectively), but there were no differences between White and Black patients. Hispanic patients had lower odds for 30-day readmission for DLEU at any diagnostic position compared to White patients (OR 0.68, 95% CI 0.54, 0.86). When isolating index admissions with ICD-10 codes for lower extremity amputation, Black patients had a 27% lower odds of 30-day all-cause readmission after admission for DLEU compared to White patients (OR 0.75, 95% CI 0.56, 0.96) (Table 3).

Discussion

In our sample size of 23,209 claims with a diagnosis of DLEU at any position, unadjusted analyses revealed 20% higher odds of 30-day all cause readmission after an admission for DLEU in Black patients compared to White patients (OR 1.20, 95% CI 1.13, 1.27). The adjusted odds ratio (AOR) in the final model was not significant after accounting for individual-level and hospital-level covariates (AOR 1.05, 95% CI 0.98, 1.12, $p = 0.14$). These covariates may capture some of the social and structural differences attributed to race and ethnicity in unadjusted analysis.

The individual-level characteristics which were significant in the final model included age, Elixhauser 30-day readmission index, payer (specifically Medicare), index admission length of stay, and patient's rural urban continuum classification (specifically, nonmetropolitan area adjacent to metropolitan area). Age and Elixhauser 30-day readmission index are associated with comorbidity burden and severity of disease. Index admission length of stay may be indicative of severity of disease or complicated social needs necessitating longer hospital stays while awaiting placement. Payer and patient's rural urban continuum code may reflect the patient's access to care along with socioeconomic factors. While our sensitivity analyses revealed lower odds ratios of readmission for Hispanic and Native American/Other groups compared to White patients, this may be an artifact of small sample size. Interestingly, social vulnerability index was not significant in our final model. While this variable has been used to reflect social determinants of health in other studies, it may capture similar disparities as payer status, length of stay, and the patient's rural urban continuum classification in our study. Furthermore, because social vulnerability index is based on county-level statistics, it approximates but does not accurately reflect individual-level vulnerability.

In Remington et al.'s adjusted analysis of 25,911 discharges in Florida and New York from 2011-2012, 30-day all-cause readmission to inpatient or ED setting was found to be associated with Black race (AOR: 1.21, 95% CI 1.13, 1.29, p = <0.001) and Hispanic race (AOR 1.11, 95% CI 1.03, 1.21, p = 0.006).[20] Similar to our analysis, variables in Remington et al.'s regression model included Elixhauser comorbidity index, age, sex, and payer. However, unlike our analysis, Remington et al. also included a variable for amputation procedure and elective status of the index admission.. Reasons for our difference in findings can include no adjustment for amputation status or elective admission status in our model, a change from ICD-9 to ICD-10 coding standards which can affect identification of cases, a smaller sample size of Hispanic patients, assessment of inpatient admissions only (excluding emergency department visits), and different state health infrastructures and disease prevalence. Our sensitivity analysis of admissions with procedure codes for lower extremity amputation found that Black patients had a 27% lower odds of 30-day all-cause readmission after admission for DLEU compared to White patients (OR 0.75, 95% CI 0.56, 0.96) (Table 3). However, racial differences were not significant for 90-day all-cause readmissions and same-year all cause readmissions after admission for diabetic lower extremity amputation (Appendix Table 1).

In studying race and ethnicity as exposures, we acknowledge that they serve as proxies for social and structural determinants of health.[38] Our analysis further reinforces this with the attenuating significance of race and ethnicity after introducing individual-level factors. Collecting data that can reflect social and structural factors accurately can help prevent misattribution of risk and subsequent interventions towards incorrect causes. In this analysis, variables such as household income, education level, and social needs would help our ability to better understand the relationship between social inequities and diabetic lower extremity ulcer readmissions.

Limitations of our study include attributing area-level characteristics to individuals, such as county-level rural urban continuum classification or quartile of median income of zip code. As this is secondary analysis of claims data, data entry and diagnoses can be coder dependent and may not be uniform. While a large percent of Georgia's hospitals is captured by the State

Inpatient Database, the hospitals not covered may have data which could be informative to our analysis. For example, the Veterans Administration hospitals in Georgia may care for more men and patients in rural areas, skewing our sample population. Our analysis focuses on Georgia and the demographic makeup and healthcare infrastructure may not be comparable to all states in the U.S. We did not include covariates for severity of lower extremity ulcer, elective admission status, or presence of amputation, which may be a future avenue for analysis. Our data is limited to inpatient hospitalization and does not cover utilization of outpatient or emergency room services. Further analyses could incorporate procedure-level and ulcer severity covariates and assess readmissions in counties classified in the diabetes belt compared to those not in the diabetes belt.

Conclusion

There was no statistical difference in the odds of 30-day all-cause readmission after admission for DLEU by race and ethnicity after adjusted for individual-level and hospital-level covariates. Race and ethnicity serve as proxies for social and structural determinants of health and collecting data towards these factors may help avoid misattribution of risk in secondary data analysis.

Tables and Figures

Figure 1: Study Sample Development

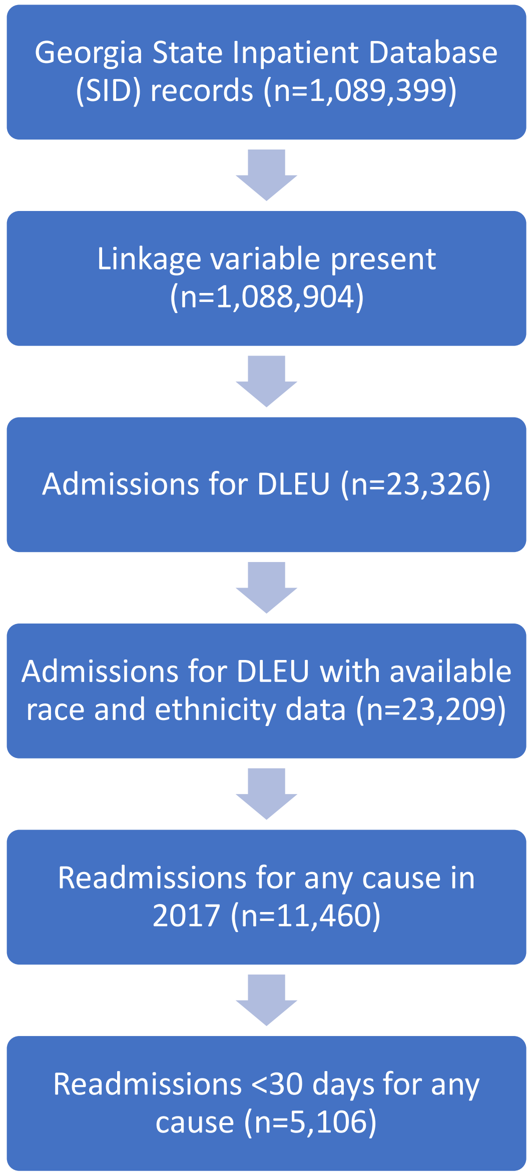


Table 1: Patient's Demographic Characteristics and Hospital Characteristics for Each Inpatient Admission by Patient Race and Ethnicity, Georgia, 2017[a]

	Race and Ethnicity[b, c]						
Individual or Hospital Characteristic[d, e]	**Total**	**White**	**Black**	**Hispanic**	**Asian or Pacific Islander**	**Native American / Other**	**p-value[f]**
Admission Counts							
Count of Admissions with DLEU Diagnosis	23,209	12938 (56%)	8919 (38%)	814 (4%)	139 (1%)	399 (2%)	<0.001
Count of DLEU Admissions with All-Cause Readmission in 2017	11,460	6228 (54%)	4667 (41%)	352 (3%)	58 (1%)	155 (1%)	<0.001
Count of DLEU Admissions with All-Cause Readmission <30 days	5,106	2844 (56%)	2008 (39%)	159 (3%)	26 (1%)	69 (1%)	<0.001
Count of DLEU Admissions with DLEU Readmission in 2017	6177	3385 (55%)	2497 (40%)	168 (3%)	27 (0.4%)	100 (2%)	<0.001
Count of DLEU Admissions with DLEU Readmission <30 days	3573	1923 (54%)	1491 (42%)	87 (2%)	13 (0.3%)	59 (2%)	<0.001

Mean Age (sd)	62.44	63.84 (13.31)	60.75 (14.37)	58.93 (13.68)	63.57 (14.34)	61.21 (14.08)	<0.001
Sex							
Male	13,779	7945 (58%)	4910 (36%)	555 (4%)	102 (1%)	267 (2%)	<0.001
Female	9,430	4993 (53%)	4009 (43%)	259 (3%)	37 (0%)	132 (1%)	
Quartile for Median Household Income of Individual's Zip Code							
$1 - $43,999	10,502	4842 (46%)	5105 (49%)	364 (3%)	35 (0%)	156 (1%)	<0.001
$44,000 - $55,999	6,315	3615 (57%)	2252 (36%)	281 (4%)	45 (1%)	122 (2%)	
$56,000 - $73,999	3,949	2703 (68%)	1048 (27%)	104 (3%)	26 (1%)	68 (2%)	
$74,000 +	2,168	1628 (75%)	407 (19%)	51 (2%)	33 (2%)	49 (2%)	
Median Elixhauser 30-day Readmission Index (IQR)	12 (6 - 19)	11 (5-18)	14 (7-21)	10 (4-17)	13 (6-20)	9 (4-17)	<0.001
Mean Index Admission Length of Stay (sd)	8.84 (10.02)	8.09 (8.78)	9.87 (11.16)	7.48 (6.06)	10.61 (11.73)	10.81 (17.96)	<0.001
Median Social Vulnerability Index Score (IQR)	0.3924 (0.2025 - 0.6519)	0.3418 (0.1456-0.6076)	0.4494 (0.2785-0.7287)	0.5063 (0.2089-0.5823)	0.2025 (0.1329-0.4494)	0.3418 (0.2025-0.4620)	<0.001
Payer							
Medicare	14,529	8239 (57%)	5592 (38%)	438 (3%)	75 (1%)	185 (1%)	<0.001
Medicaid	2,377	1065 (45%)	1147 (48%)	101 (4%)	16 (1%)	48 (2%)	
Private	3,411	2112 (62%)	1120 (33%)	95 (3%)	14 (0%)	70 (2%)	

Self-pay, no-charge, other, or missing	2888	1512 (52%)	1049 (36%)	180 (6%)	34 (1%)	96 (3%)	
County-Level Rural Urban Continuum Code							
Metropolitan	17,628	9402 (53%)	7153 (41%)	619 (4%)	134 (1%)	320 (2%)	<0.001
Nonmetropolitan area adjacent to metropolitan area	4,063	2537 (62%)	1310 (32%)	177 (4%)	[g]	36 (1%)	
Nonmetropolitan area not adjacent to metropolitan area	1,498	993 (66%)	447 (30%)	15 (1%)	[g]	41 (3%)	
Hospital Bed Size							
6-99 beds	2750	1715 (62%)	907 (33%)	25 (1%)	[g]	93 (3%)	<0.001
100-299 beds	7383	4933 (67%)	2154 (29%)	151 (2%)	53 (1%)	92 (1%)	
300-499 beds	5987	2500 (42%)	2951 (49%)	458 (8%)	25 (0%)	53 (1%)	
500+ beds	7062	3773 (53%)	2897 (41%)	180 (3%)	51 (1%)	161 (2%)	
Hospital Ownership							
Regional (county, city-county, hospital district or authority)	1240	804 (65%)	396 (32%)	17 (1%)	[g]	22 (2%)	<0.001
Church	1116	740 (66%)	327 (29%)	19 (2%)	[g]	20 (2%)	
Not-for-profit	17617	9442 (54%)	7006 (40%)	740 (4%)	121 (1%)	308 (2%)	
Private (individual, partnership, corporation)	3209	1935 (60%)	1180 (37%)	38 (1%)	[g]	49 (2%)	

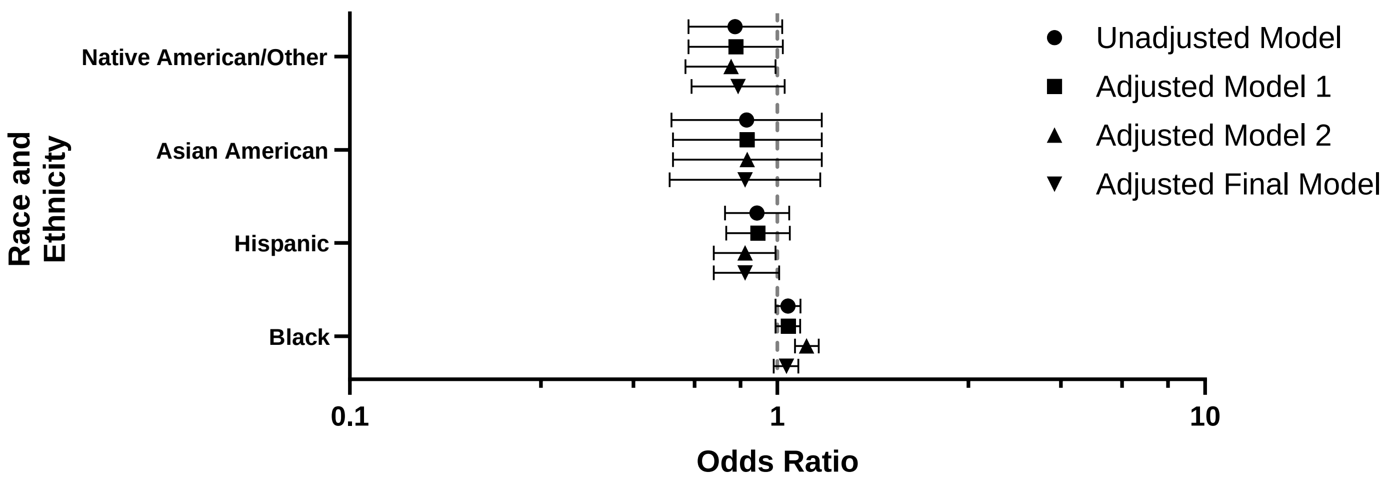
Hospital Teaching Status							
Non-teaching	9333	6210 (67%)	2703 (29%)	159 (2%)	43 (0%)	218 (2%)	<0.001
Teaching	13849	6711 (48%)	6206 (45%)	655 (5%)	96 (1%)	181 (1%)	
Hospital County-Level Metropolitan Statistical Area Classification							
Metropolitan	19817	10774 (54%)	7784 (39%)	776 (4%)	138 (1%)	345 (2%)	<0.001
Micropolitan	2714	1681 (62%)	951 (35%)	32 (1%)	[g]	49 (2%)	
Neither	651	466 (72%)	174 (27%)	[g]	[g]	5 (1%)	

DLEU = diabetic lower extremity ulcer; sd = standard deviation; IQR = interquartile range

a. Data source: Georgia State Inpatient Database, 2017 from the Healthcare Cost and Utilization Project sponsored by the Agency for Healthcare Research and Quality.
b. Native American and Other categories were merged due to low counts.
c. n = 117 records were excluded due to missing race and ethnicity information.
d. Chi-square tests were performed for categorical variables and one-way ANOVA tests were performed for continuous variables.
e. Information in parenthesis contain row percentages unless otherwise indicated.
f. $p < 0.05$ indicates statistical significance.
g. Counts < 11 are suppressed per the HCUP Data Use Agreement

Table 2 and Figure 2: Unadjusted and Adjusted Odds Ratios for 30-day Readmission after Index Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity[a]

Race and Ethnicity Category[b]	Unadjusted Odds Ratio (95% CI)	Model 1 Adjusted Odds Ratio[c] (95% CI)	Model 2 Adjusted Odds Ratio[d] (95% CI)	Final Model Adjusted Odds Ratio[e] (95% CI)
White	Reference	Reference	Reference	Reference
Black	**1.12 (1.13, 1.27)**	1.06 (0.99, 1.13)[f]	**1.17 (1.1, 1.25)**	1.05 (0.98, 1.12)[g]
Hispanic	0.88 (0.74, 1.04)	0.90 (0.76, 1.07)	**0.84 (0.71, 0.99)**	0.84 (0.71, 1.01)
Asian Or Pacific Islander	0.84 (0.59, 1.26)	0.85 (0.57, 1.27)	0.85 (0.57, 1.27)	0.84 (0.56, 1.26)
Native American + Other	0.78 (0.61, 0.99)	0.80 (0.62, 1.03)	**0.78 (0.61, 0.99)**	0.81 (0.63, 1.04)



CI = Confidence Interval

[a] Statistically significant odds ratios at $p < 0.05$ are bolded.
[b] White race is the referent group in the table and Forest Plot.
[c] Model 1 includes individual-level covariates only in addition to the primary exposure (race and ethnicity): age, payer, quartile of median-income of zip code, patient’s rural urban county classification, Elixhauser 30-day readmission index, social vulnerability index, sex, index admission length of stay.
[d] Model 2 includes hospital-level covariates only in addition to the primary exposure (race and ethnicity): hospital bed size, hospital metropolitan statistical area classification, hospital teaching status, and hospital ownership.
[e] The final model includes the following covariates in addition to race and ethnicity: age, Elixhauser 30-day readmission index, payer, length of stay of index admission, patient’s rural urban county classification, hospital bed size, hospital teaching status, and hospital metropolitan statistical area classification.
[f] $p = 0.09$
[g] $p = 0.14$

Table 3: Unadjusted and Adjusted Odd Ratios of Covariates for 30-day Readmission after Index Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity[a]

Individual or Hospital-Level Characteristic	Unadjusted Odds Ratio (95% CI)	Final Model Adjusted Odds Ratio[b] (95% CI)
Race and Ethnicity		
White	REF	REF
Black	**1.2 (1.13, 1.27)**	1.05 (0.98, 1.12)
Hispanic	0.88 (0.74, 1.04)	0.85 (0.71, 1.01)
Asian American	0.84 (0.59, 1.26)	0.84 (0.56, 1.26)
Native American/Other	0.78 (0.61, 0.99)	0.81 (0.63, 1.04)
Age	1.001 (0.999, 1.003)	**0.99 (0.99, 0.996)**
Sex		
Male	REF	
Female	0.95 (0.89, 1.001)	
Quartile for Median Household Income of Individual's Zip Code		
$1 - $43,999	1.13 (1.02, 1.26)	
$44,000 - $55,999	1.09 (0.98, 1.22)	
$56,000 - $73,999	1.01 (0.89, 1.13)	
$74,000 +	REF	
Elixhauser 30-day Readmission Index	**1.04 (1.03, 1.04)**	**1.03 (1.03, 1.04)**
Index Admission Length of Stay	**1.02 (1.01, 1.02)**	**1.01 (1.01, 1.01)**
Social Vulnerability Index Score	**1.3 (1.16, 1.46)**	

Payer		
Medicare	**1.41 (1.29, 1.54)**	**1.28 (1.16, 1.41)**
Medicaid	**1.26 (1.12, 1.42)**	1.12 (0.99, 1.27)
Private	REF	REF
Self-pay, no-charge, other, or missing	0.9 (0.8, 1.01)	0.92 (0.81, 1.04)
County-Level Rural Urban Continuum Code		
Metropolitan	REF	REF
Nonmetropolitan area adjacent to metropolitan area	**1.13 (1.05, 1.22)**	**1.24 (1.12, 1.36)**
Nonmetropolitan area not adjacent to metropolitan area	0.97 (0.86, 1.09)	1.12 (0.97, 1.3)
Hospital Bed Size		
6-99 beds	1.09 (0.99, 1.21)	
100-299 beds	0.96 (0.89, 1.03)	
300-499 beds	**1.18 (1.09, 1.27)**	
500+ beds	REF	
Hospital Ownership		
Regional (county, city-county, hospital district or authority)	0.87 (0.75, 1.01)	1.09 (0.96, 1.22)
Church	0.86 (0.74, 1.01)	0.99 (0.91, 1.08)
Not-for-profit	**0.89 (0.82, 0.97)**	**1.15 (1.06, 1.25)**
Private (individual, partnership, corporation)	REF	REF

Hospital Teaching Status		
Non-teaching	REF	REF
Teaching	**1.1 (1.03, 1.16)**	**1.09 (1.01, 1.18)**
Hospital County-Level Metropolitan Statistical Area Classification		
Metropolitan	REF	REF
Micropolitan	0.98 (0.9, 1.07)	0.92 (0.81, 1.04)
Neither	1.02 (0.86, 1.22)	1.21 (0.98, 1.5)

CI = confidence interval; REF = reference group;

a. Statistically significant odds ratios at $p < 0.05$ are bolded.
b. The final model includes the following covariates in addition to race and ethnicity: age, Elixhauser 30-day readmission index, payer, length of stay of index admission, patient's rural urban county classification, hospital bed size, hospital teaching status, and hospital metropolitan statistical area classification.

Figure 3: Unadjusted Odd Ratios of Covariates for 30-day Readmission after Index Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity

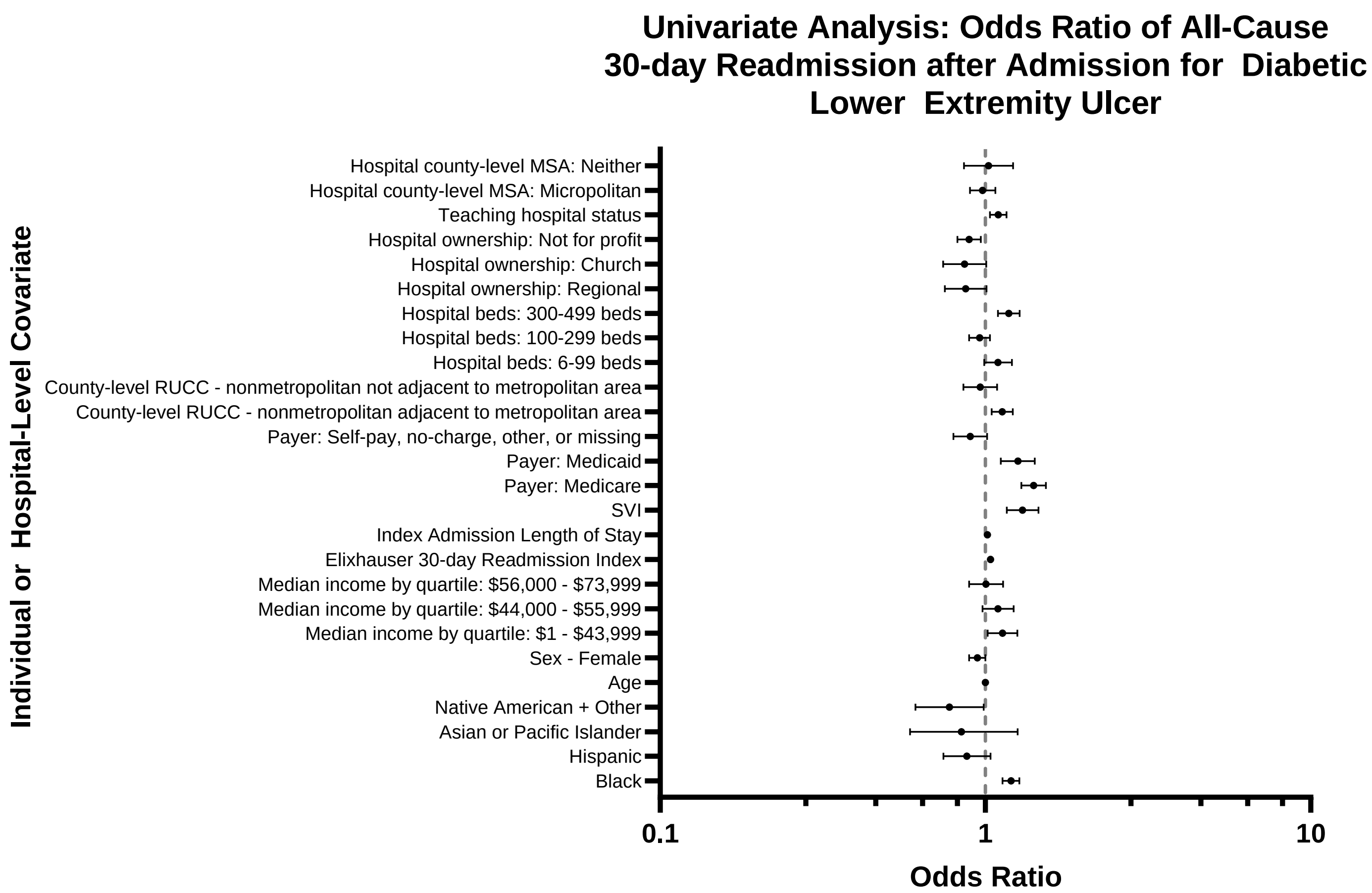


Figure 4: Adjusted Odd Ratios of Covariates for 30-day Readmission after Index Admission for Diabetic Lower Extremity Ulcer by Race and Ethnicity

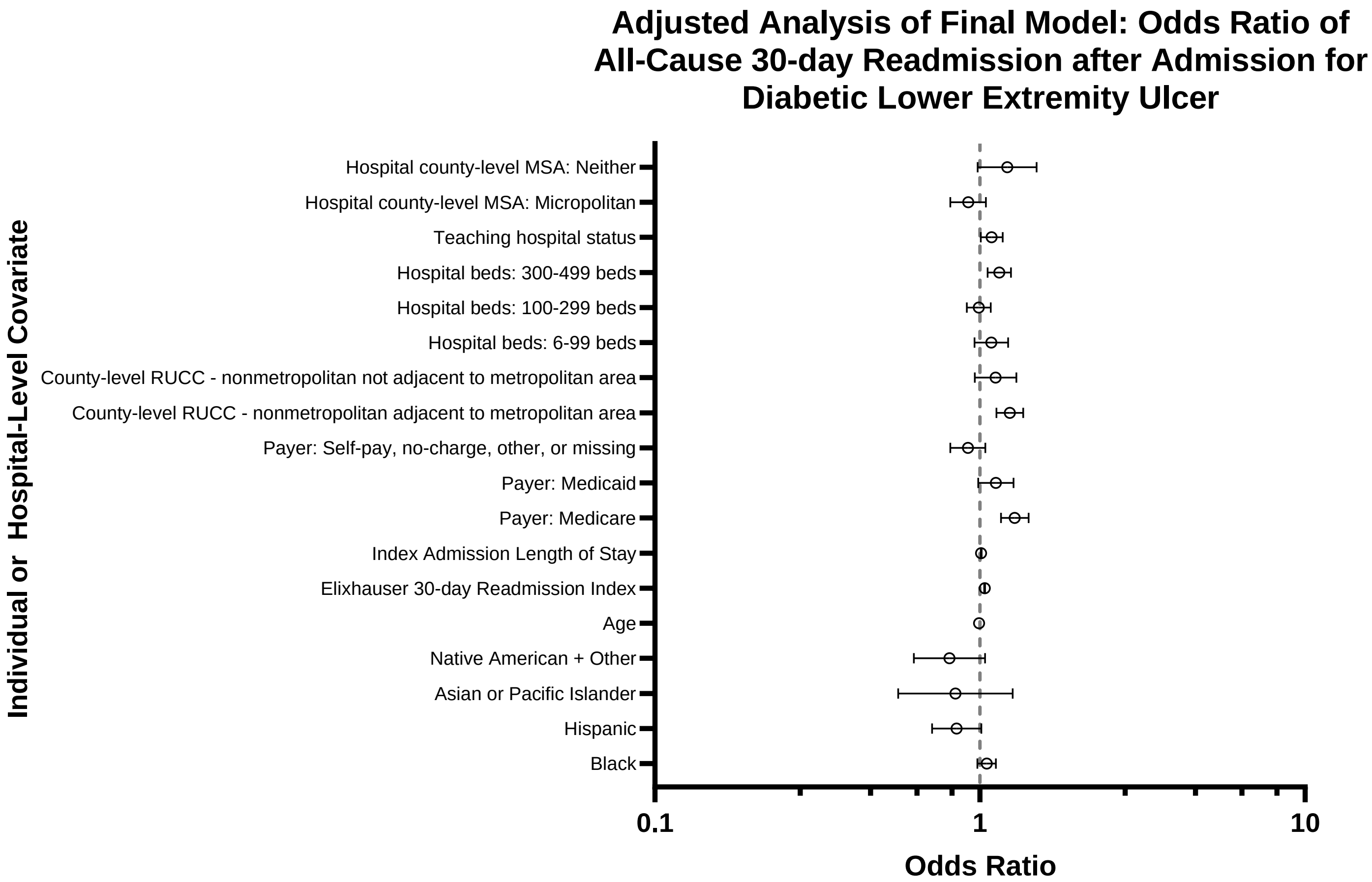


Table 4: Adjusted Odds Ratio for Sensitivity Analyses Endpoints after Admission for Diabetic Lower Extremity Ulcer[a, b]

Race and Ethnicity Category[c]	AOR: 30-Day All-Cause Readmission (95% CI)	AOR: All-Cause Readmission In 2017 (95% CI)	AOR: 90-Day All-Cause Readmission (95% CI)	AOR: 30-Day Readmission For Diabetic Lower Extremity Ulcer[d] (95% CI)	AOR: 30-Day All-Cause Readmission After Major Amputation Procedure (95% CI) [e]
White	Reference	Reference	Reference	Reference	Reference
Black	1.04 (0.97, 1.11)	1.02 (0.96, 1.09)	1.05 (0.99, 1.12)	1.07 (0.98, 1.16)	**0.73 (0.56, 0.96)**
Hispanic	0.85 (0.71, 1.01)	**0.79 (0.67, 0.92)**	0.85 (0.71, 1.01)	**0.68 (0.54, 0.86)**	0.74 (0.37, 1.49)
Asian Or Pacific Islander	0.84 (0.56, 1.27)	0.78 (0.56, 1.10)	0.82 (0.55, 1.23)	0.59 (0.33, 1.05)	1.16 (0.31, 4.37)
Native American + Other	0.80 (0.62, 1.04)	**0.72 (0.58, 0.89)**	0.81 (0.63, 1.04)	1.00 (0.74, 1.34)	0.66 (0.25, 1.75)

AOR = adjusted odds ratio; CI = confidence interval

a. Statistically significant odds ratios at $p < 0.05$ are bolded.
b. Models for sensitivity analysis include all individual and hospital level covariates, with varying outcomes as shown in the columns.
c. White race is the referent group in the table.
d. Readmission for DLEU at any diagnostic position.
e. Major amputation ICD-10 codes as previously used by Lobo et al., 2023: 0Y620ZZ, 0Y630ZZ, 0Y640ZZ, 0Y670ZZ, 0Y680ZZ, 0Y6C0Z1, 0Y6C0Z2, 0Y6C0Z3, 0Y6D0Z1, 0Y6D0Z2, 0Y6D0Z3, 0Y6F0ZZ, 0Y6G0ZZ, 0Y6H0Z1, 0Y6H0Z2, 0Y6H0Z3, 0Y6J0Z1, 0Y6J0Z2, 0Y6J0Z3

Chapter 3: Future Directions

Although our findings did not reveal disparities by race and ethnicity for 30-day all-cause readmissions after an initial admission for diabetic lower extremity ulcer (DLEU) in Georgia in 2017, our methodology may have implications on DLEU research and on public health research.

We employed a new standard proposed by Fowler et al. of ICD-10 codes to identify DLEU.[29] Although there are no other published studies using this standard yet, we hope that it has increased adoption because there is no widely accepted standard in administrative data analysis for DLEU using ICD-10 codes. Currently, there are a limited number of secondary data analyses of DLEU using ICD-10 codes, likely due to the relative newness of the ICD-10 release (ICD-10 was widely adopted in 2015[39]), lack of established consensus on methodology for analysis, and complexity of the ICD-10 coding scheme. For example, Fowler et al. identified 45 codes in ICD-9 compared to 304 codes in ICD-10 to capture diabetic lower extremity disease in administrative database analyses.[29] Establishing a consensus methodology on analyzing DLEU would enable more research and improve our ability to compare findings and understand the burden of disease and disparities. This consensus standard would be especially effective if endorsed by a professional organization, such as American Podiatric Medical Association, American Diabetes Association, or federal agency, such as the Agency for Healthcare Research and Quality.

In our analysis, we aimed to incorporate as many factors reflecting social determinants of health as the data allowed, including county-level social vulnerability index scores and rurality measures. After adjusting for these variables, we found that race was not a significant contributor to all-cause 30-day readmissions after an index admission for DLEU. We hope that our analysis demonstrates how race can serve as a confounder for social and systemic inequities. We also found that the patient's county-level rural urban continuum code was a significant covariate. However, this reflects area-level information, which approximates but is not equivalent to individual-level information. We thus identify a need for appropriate demographic and social information at the individual-level and area-level to enable more accurate analyses of disparities and a clearer target for intervention.

Future steps from this analysis include advocating for the collection of more detailed individual-level variables reflecting social determinants of health, such as income, food insecurity, and housing insecurity. Further analyses can include assessing DLEU readmissions by specific social determinants of health (such as payer), ulcer severity, amputation procedures, and areas in Georgia. Furthermore, as race/ethnicity intersects with social determinants of health, involving it as a covariate in analyses would necessitate careful interpretation in the presence other variables.

This is the first administrative database analysis on DLEU in Georgia. As our data focused on 2017 inpatient admissions, we hope that it can serve as a comparator for future analyses, especially to assess trends and impacts from the Covid-19 pandemic or health policies, such as Medicaid expansion.

References

1. Centers for Disease Control and Prevention. National Diabetes Statistics Report. Accessed June 16, 2024. https://www.cdc.gov/diabetes/php/data-research/index.html

2. Zhang P, Lu J, Jing Y, Tang S, Zhu D, Bi Y. Global epidemiology of diabetic foot ulceration: a systematic review and meta-analysis (dagger). *Ann Med*. Mar 2017;49(2):106-116. doi:10.1080/07853890.2016.1231932

3. McDermott K, Fang M, Boulton AJM, Selvin E, Hicks CW. Etiology, Epidemiology, and Disparities in the Burden of Diabetic Foot Ulcers. *Diabetes Care*. Jan 1 2023;46(1):209-221. doi:10.2337/dci22-0043

4. Armstrong DG, Tan TW, Boulton AJM, Bus SA. Diabetic Foot Ulcers: A Review. *JAMA*. Jul 3 2023;330(1):62-75. doi:10.1001/jama.2023.10578

5. Chen L, Sun S, Gao Y, Ran X. Global mortality of diabetic foot ulcer: A systematic review and meta-analysis of observational studies. *Diabetes Obes Metab*. Jan 2023;25(1):36-45. doi:10.1111/dom.14840

6. Georgia Department of Public Health. Diabetes. Updated Sept 14, 2023. Accessed June 15, 2024. https://dph.georgia.gov/chronic-disease-prevention/diabetes

7. American Diabetes Association. Statistics About Diabetes. Updated November 2, 2023. Accessed June 15, 2024. https://diabetes.org/about-diabetes/statistics/about-diabetes

8. Margolis DJ, Malay DS, Hoffstad OJ, et al. Prevalence of diabetes, diabetic foot ulcer, and lower extremity amputation among Medicare beneficiaries, 2006 to 2008: Data Points #1. *Data Points Publication Series*. 2011.

9. Brennan MB, Powell WR, Kaiksow F, et al. Association of Race, Ethnicity, and Rurality With Major Leg Amputation or Death Among Medicare Beneficiaries Hospitalized With

Diabetic Foot Ulcers. *JAMA Netw Open*. Apr 1 2022;5(4):e228399. doi:10.1001/jamanetworkopen.2022.8399

10. Miller TA, Campbell JH, Bloom N, Wurdeman SR. Racial Disparities in Health Care With Timing to Amputation Following Diabetic Foot Ulcer. *Diabetes Care*. Oct 1 2022;45(10):2336-2341. doi:10.2337/dc21-2693

11. Tan TW, Armstrong DG, Concha-Moore KC, et al. Association between race/ethnicity and the risk of amputation of lower extremities among medicare beneficiaries with diabetic foot ulcers and diabetic foot infections. *BMJ Open Diabetes Res Care*. Aug 2020;8(1)doi:10.1136/bmjdrc-2020-001328

12. Georgia Department of Public Health. 2020 Georgia Diabetes Report and Action Plan. Accessed June 15, 2024. https://www.sehdph.org/wp-content/uploads/2023/01/Diabetes-Action-Plan-2020.pdf

13. Centers for Disease Control and Prevention. U.S. Diabetes Surveillance System website. Accessed July 17, 2024. https://gis.cdc.gov/grasp/diabetes/diabetesatlas-surveillance.html

14. Rice JB, Desai U, Cummings AK, Birnbaum HG, Skornicki M, Parsons NB. Burden of diabetic foot ulcers for medicare and private insurers. *Diabetes Care*. 2014;37(3):651-8. doi:10.2337/dc13-2176

15. Margolis DJ, Malay DS, Hoffstad OJ, et al. Economic burden of diabetic foot ulcers and amputations: Data Points #3. *Data Points Publication Series*. 2011.

16. Centers for Medicare & Medicaid Services CfMCS. Guidance for Calculating the Plan All-Cause Readmissions (PCR) Measure in the 2020 Adult and Health Home Core Sets. Accessed June 25, 2024. https://www.hhs.gov/guidance/sites/default/files/hhs-guidance-

documents/2020.plan%2520all-cause%2520readmissions%2520measure%2520fact%2520sheet.pdf

17. CMS Office of Minority Health. Guide for Reducing Disparities in Readmissions. Accessed June 25, 2024. https://www.cms.gov/about-cms/agency-information/omh/downloads/omh_readmissions_guide.pdf

18. CMS.gov. Hospital Readmissions Reduction Program (HRRP). Updated Sept 6, 2023. Accessed June 25, 2024. https://www.cms.gov/medicare/quality/value-based-programs/hospital-readmissions

19. Holscher CM, Hicks CW, Canner JK, et al. Unplanned 30-day readmission in patients with diabetic foot wounds treated in a multidisciplinary setting. *J Vasc Surg*. Mar 2018;67(3):876-886. doi:10.1016/j.jvs.2017.07.131

20. Remington AC, Hernandez-Boussard T, Warstadt NM, et al. Analyzing treatment aggressiveness and identifying high-risk patients in diabetic foot ulcer return to care. *Wound Repair Regen*. Jul 2016;24(4):731-6. doi:10.1111/wrr.12439

21. Press VG, Myers LC, Feemster LC. Preventing COPD Readmissions Under the Hospital Readmissions Reduction Program: How Far Have We Come? *Chest*. Mar 2021;159(3):996-1006. doi:10.1016/j.chest.2020.10.008

22. Myers AK, Dawkins M, Baskaran I, et al. Laboratory and Pharmaceutical Data Associated With Hospital Readmission in Persons With Diabetic Foot Ulcers. *Inquiry*. Jan-Dec 2021;58:469580211060779. doi:10.1177/00469580211060779

23. Hicks CW, Canner JK, Karagozlu H, et al. Contribution of 30-day readmissions to the increasing costs of care for the diabetic foot. *J Vasc Surg*. Oct 2019;70(4):1263-1270. doi:10.1016/j.jvs.2018.12.028

24. Hingorani A, LaMuraglia GM, Henke P, et al. The management of diabetic foot: A clinical practice guideline by the Society for Vascular Surgery in collaboration with the American Podiatric Medical Association and the Society for Vascular Medicine. *J Vasc Surg*. Feb 2016;63(2 Suppl):3S-21S. doi:10.1016/j.jvs.2015.10.003

25. Barker LE, Kirtland KA, Gregg EW, Geiss LS, Thompson TJ. Geographic distribution of diagnosed diabetes in the U.S.: a diabetes belt. *Am J Prev Med*. Apr 2011;40(4):434-9. doi:10.1016/j.amepre.2010.12.019

26. Agency for Healthcare Research and Quality HCaUP. Overview of the State Inpatient Databases (SID). Accessed June 20, 2024. https://hcup-us.ahrq.gov/sidoverview.jsp

27. Agency for Healthcare Research and Quality HCaUP. Comparison of Hospitals and Records in the 2017 HCUP State Inpatient Databases (SID) to the 2017 American Hospital Association (AHA) Survey of Hospitals. Accessed June 20, 2024. https://hcup-us.ahrq.gov/db/state/siddist/2017CountsSIDdischargeshosps.pdf

28. Agency for Healthcare Research and Quality HCaUP. Introduction to the HCUP State Inpatient Databases. Accessed June 20, 2022. https://hcup-us.ahrq.gov/db/state/siddist/Introduction_to_SID.pdf

29. Fowler XP, Eid MA, Barnes JA, et al. Deriving International Classification of Diseases, 9th and 10th revision, codes for identifying and following up patients with DLEU. *J Vasc Surg Cases Innov Tech*. Dec 2022;8(4):877-884. doi:10.1016/j.jvscit.2022.10.003

30. Agency for Healthcare Research and Quality HCaUP. HCUP State Inpatient Databases (SID) Availability of Data Elements - 2017. Accessed June 10, 2024. https://hcup-us.ahrq.gov/db/state/siddist/siddistvarnote2017.jsp

31. Agency for Healthcare Research and Quality HCaUP. Elixhauser Comorbidity Software Refined for ICD-10-CM Accessed June 10, 2024. https://hcup-us.ahrq.gov/toolssoftware/comorbidityicd10/comorbidity_icd10.jsp#:~:text=The%20Elixhauser%20Comorbidity%20Software%20Refined,for%20Healthcare%20Research%20and%20Quality.

32. Agency for Healthcare Research and Quality HCaUP. User Guide: Elixhauser Comorbidity Software Refined for ICD-10-CM, v2024.1 Accessed June 10, 2024. https://hcup-us.ahrq.gov/toolssoftware/comorbidityicd10/CMR-User-Guide-v2024-1.pdf

33. Agency for Toxic Substances and Disease Registry. CDC/ATSDR SVI Overview. Accessed June 10, 2024. https://www.atsdr.cdc.gov/placeandhealth/svi/index.html

34. Tran T, Rousseau MA, Farris DP, Bauer C, Nelson KC, Doan HQ. The social vulnerability index as a risk stratification tool for health disparity research in cancer patients: a scoping review. *Cancer Causes Control*. May 2023;34(5):407-420. doi:10.1007/s10552-023-01683-1

35. Jain V, Al Rifai M, Khan SU, et al. Association Between Social Vulnerability Index and Cardiovascular Disease: A Behavioral Risk Factor Surveillance System Study. *J Am Heart Assoc*. Aug 2 2022;11(15):e024414. doi:10.1161/JAHA.121.024414

36. Lobo JM, Kang H, Brennan MB, et al. Regional and racial disparities in major amputation rates among medicare beneficiaries with diabetes: a retrospective study in the southeastern USA. *BMJ Public Health*. 2023;1(1)doi:10.1136/bmjph-2023-000206

37. *SAS, Version 9.4*. SAS Institute; 2013.

38. Rollin FG, Washington C, Fluker SA. Using race as a social construct when looking at differences in racial associations between non-alcoholic fatty liver disease and type 2 diabetes. *Diabetologia*. Jan 2024;67(1):211-212. doi:10.1007/s00125-023-05998-1

39. Agency for Healthcare Research and Quality HCaUP. Central Distributor SID: Description of Data Elements: I10_DX_Admitting - Admitting ICD-10-CM Diagnosis Code. Accessed June 20, 2024. https://hcup-us.ahrq.gov/db/vars/siddistnote.jsp?var=i10_dx_admitting

Appendix

Appendix Table 1: Adjusted Odds Ratio for Further Sensitivity Analyses Endpoints after Admission for Diabetic Lower Extremity Ulcer with Major Amputation [a, b, c]

Race and Ethnicity Category[d]	**AOR: 30-Day All-Cause Readmission After Major Amputation Procedure (95% CI) [e] (n = 1265)**	**AOR: 90-Day All-Cause Readmission After Major Amputation Procedure (95% CI) [e] (n = 1265)**	**AOR: Same-Year All-Cause Readmission After Major Amputation Procedure (95% CI) [e] (n = 1265)**
White	Reference	Reference	Reference
Black	0.73 (0.56, 0.96)	1.01 (0.78, 1.30)	1.26 (0.98, 1.64)
Hispanic	0.74 (0.37, 1.49)	0.67 (0.34, 1.33)	0.85 (0.43, 1.67)
Asian Or Pacific Islander	1.16 (0.31, 4.37)	1.86 (0.50, 6.91)	2.37 (0.57, 9.78)
Native American + Other	0.66 (0.25, 1.75)	0.94 (0.37, 2.43)	1.20 (0.47, 3.11)

AOR = adjusted odds ratio; CI = confidence interval

a. Statistically significant odds ratios at $p < 0.05$ are bolded.
b. Models for sensitivity analysis include all individual and hospital level covariates, with varying outcomes as shown in the columns.
c. Major amputation ICD-10 codes as previously used by Lobo et al., 2023: 0Y620ZZ, 0Y630ZZ, 0Y640ZZ, 0Y670ZZ, 0Y680ZZ, 0Y6C0Z1, 0Y6C0Z2, 0Y6C0Z3, 0Y6D0Z1, 0Y6D0Z2, 0Y6D0Z3, 0Y6F0ZZ, 0Y6G0ZZ, 0Y6H0Z1, 0Y6H0Z2, 0Y6H0Z3, 0Y6J0Z1, 0Y6J0Z2, 0Y6J0Z3
d. White race is the referent group in the table.
e. Readmission for DLEU at any diagnostic position.