# Racial, Rural, and Regional Disparities in Diabetes-Related Lower-Extremity Amputation Rates, 2009–2017

Diabetes Care 2021;44:2053–2060 | https://doi.org/10.2337/dc20-3135

Marvellous A. Akinlotan,[1,2] Kristin Primm,[1,3] Jane N. Bolin,[1,2,4] Abdelle L. Ferdinand Cheres,[5] JuSung Lee,[1,6] Timothy Callaghan,[1,4] and Alva O. Ferdinand[1,4]

EPIDEMIOLOGY/HEALTH SERVICES RESEARCH


**OBJECTIVE**

**To examine the racial/ethnic, rural-urban, and regional variations in the trends of diabetes-related lower-extremity amputations (LEAs) among hospitalized U.S. adults from 2009 to 2017.**

**RESEARCH DESIGN AND METHODS**

**We used the National Inpatient Sample (NIS) (2009–2017) to identify trends in LEA rates among those primarily hospitalized for diabetes in the U.S. We conducted multivariable logistic regressions to identify individuals at risk for LEA based on race/ethnicity, census region location (North, Midwest, South, and West), and rurality of residence.**

**RESULTS**

**From 2009 to 2017, the rates of minor LEAs increased across all racial/ethnic, rural/urban, and census region categories. The increase in minor LEAs was driven by Native Americans (annual percent change [APC] 7.1%, $P < 0.001$) and Asians/Pacific Islanders (APC 7.8%, $P < 0.001$). Residents of non-core (APC 5.4%, $P < 0.001$) and large central metropolitan areas (APC 5.5%, $P < 0.001$) experienced the highest increases over time in minor LEA rates. Among Whites and residents of the Midwest and non-core and small metropolitan areas there was a significant increase in major LEAs. Regression findings showed that Native Americans and Hispanics were more likely to have a minor or major LEA compared with Whites. The odds of a major LEA increased with rurality and was also higher among residents of the South than among those of the Northeast. A steep decline in major–to–minor amputation ratios was observed, especially among Native Americans.**

**CONCLUSIONS**

**Despite increased risk of diabetes-related lower-limb amputations in underserved groups, our findings are promising when the major–to–minor amputation ratio is considered.**


In the U.S., diabetes alone accounts for more than 100,000 nontraumatic lower-limb amputations per year (1) and over $50,000 in work force disability and related costs per patient (2). Individuals with diabetes are at increased risk of peripheral vascular disease, peripheral neuropathy, and foot ulcers, which are predisposing

[1]Southwest Rural Health Research Center, Texas A&M University School of Public Health, College Station, TX
[2]College of Nursing, Texas A&M University, Bryan, TX
[3]Department of Epidemiology, The University of Texas MD Anderson Cancer Center, Houston, TX
[4]Department of Health Policy & Management, Texas A&M University, College Station, TX
[5]University Hospitals - Portage, Geagua and Ahuja Medical Centers Department of Endocrinology, Diabetes and Metabolism, Cleveland, OH
[6]Department of Public Health, University of Texas at San Antonio, San Antonio, TX

Corresponding author: Marvellous A. Akinlotan, akinlotan@tamu.edu

Received 24 December 2020 and accepted 20 June 2021

This article contains supplementary material online at https://doi.org/10.2337/figshare.14823504.

factors for lower-extremity amputations (LEAs) (3). Diabetes-related LEA is responsible for significant negative and disabling effects for individuals including loss of employment, loss of health insurance, significantly higher hospitalization rates, and shorter life expectancy (4,5). In the U.S., amputation rates per 1,000 adults with diabetes decreased 43% between 2000 and 2009 (6) and has been largely attributed to improvements in diabetes care and identification of risk factors among different groups (7). Moreover, these declines were driven by LEA reductions among older adults, though the reasons for the decline within this age-group are unknown (7). However, recent studies have drawn attention to the resurgence of minor amputations, particularly among young and middle-aged adults (6,8).

Many sociodemographic factors such as race/ethnicity, poverty, and insurance status contribute to observed variations in diabetes severity as it relates to likelihood of LEA (1,9,10). There is ample evidence that Black and Hispanic populations are disproportionately affected by both diabetes and LEA compared with White populations (9,11). In addition, regional and rural-urban variations in the burden of diabetes and LEA have also been reported (11–14). For example, among Medicare beneficiaries with diabetes, Margolis et al. (13) (2011) identified regional clusters with increased LEA risk in the contiguous states of the South census region, while Yin et al. (15) (2013) reported on the regional variation in hospitalization costs among patients with diabetes who went through LEA, with higher costs in the West census region. Other studies have reported on the increased incidence of LEA among rural residents in the emergency department (16,17).

Recent studies using national data have examined aspects of LEA such as the trends in minor and major LEA with an emphasis on age and sex variations (6), and racial/ethnic differences, in amputation rates among individuals with diabetes hospitalized for diabetic foot ulcers and infections (8,18). However, no prior studies shed light on geographical variation in trends in rates of LEA, particularly across the urban-rural continuum and census regions. In addition, these studies are now somewhat dated, with data examined only up to 2015. Therefore, a more contemporary analysis is needed. The purpose of this study was to examine the racial/ethnic, rural, and regional trends in minor and major LEA among adults with diabetes who are hospitalized in the U.S. The secondary aim was to identify the sociodemographic factors associated with the risk of a minor or major LEA among adults hospitalized with diabetes.

## RESEARCH DESIGN AND METHODS

### Data Source

This retrospective, observational study was conducted using data obtained from the Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS) for the years 2009–2017. The NIS is developed through a federal-state-industry partnership and is made available by the Agency for Healthcare Research and Quality (AHRQ). It is the largest all-payer hospital inpatient database in the U.S. Unweighted: the NIS includes data from more than seven million discharges from U.S. community hospitals annually. Weighted: the NIS estimates >35 million hospital stays nationally each year (19).

### Study Sample

The NIS contains information on ICD-9 and ICD-10, Clinical Modification (ICD-9-CM and ICD-10-CM/Procedure Classification System [PCS]) diagnoses and procedure codes for each hospital stay. AHRQ's Clinical Classifications Software (CCS) codes categorize ICD-9-CM and ICD-10-CM diagnosis codes into clinically meaningful categories (20). Admissions for diabetes without complications were identified in the NIS with CCS codes 49 (for ICD-9-CM codes) and 3.2 (for ICD-10-CM codes), and admissions for diabetes with complications were identified with CCS codes 50 and 3.3 for ICD-9-CM and ICD-10-CM codes, respectively. We limited the study sample to patients discharged with a diagnosis of diabetes as indicated in the principal diagnosis fields to capture patients who primarily were admitted for diabetes. Discharged patients with indication of minor or major LEAs in the primary or secondary procedure codes were identified with ICD-9-CM and ICD-10-CM procedure codes shown in Appendix 1. Minor LEAs were defined as toe and foot amputations, and major LEAs were defined as amputations above the foot, below the knee, or above the knee. Consistent with previous research on LEAs, we restricted our sample to patients age ≥18 years.

### Variables

The primary outcome variable was documentation of either minor or major LEA during a diabetes-related admission in any of the procedure fields. This outcome was measured in three ways. First, we estimated the percentage of diabetes-related hospitalizations with a minor or major LEA. Second, we treated minor and major LEAs as dichotomous variables and examined the sociodemographic and clinical characteristics associated with the likelihood of a minor or major LEA during a diabetes-related admission. Third, for each racial/ethnic category, we measured the major-to-minor amputation ratio for each study year. We included this outcome recognizing that the changing trends in major and minor amputations might be a positive outcome, given the burden on some racial/ethnic groups. Where minor LEAs were examined, patients discharged with major LEAs were excluded from the analysis, and vice versa.

Our main independent variables were measures for race/ethnicity, rural/urban status of patient's residence, and census region of the admitting hospital. Race/ethnicity was coded as White, Black, Hispanic, Asian or Pacific Islander, Native American, and other. Approximately 56,906 discharge records had missing information on race. Therefore, we added a "missing" category to the race/ethnicity variable to avoid listwise deletion of these observations in the analysis. Information on the patient's residence was categorized into six levels of rurality with the 2013 National Center for Health Statistics urban-rural classification scheme: Large central metropolitan, large fringe metropolitan, medium metropolitan, small metropolitan, micropolitan, and noncore (21). Census region was categorized as North, Midwest, South, and West. Other sociodemographic control variables included age (categorized as 18–44, 45–64, 65–74, and ≥75 years); sex (male/female), primary payer (privately insured, Medicare, Medicaid, self-pay/no charge, and other), and median household income for patient's ZIP code ($1–38,999, $39,000–47,000, $48,000–62,999, and $63,000 or more). Patients' clinical characteristics such as the presence of comorbidities and prior amputation were also included as covariates.

Comorbidities were identified with use of the Charlson Comorbidity Index (22) to adjust for the number of comorbidities recorded in each admission. Discharge records in which patients had prior amputations were identified with ICD-9-CM codes V49.70 to V49.77 and ICD-10-CM codes Z894 to Z899.

### Statistical Analyses

We used the discharge weights provided in the NIS to account for the complex sampling design and to provide national estimates. In 2012, to improve national estimates, the NIS sampling methods changed from a 20% stratified sample of all hospitals to a 20% stratified sample of all discharge records from hospitals. The 1993–2011 supplemental trends weight file provided by HCUP was used to reconcile the changes in the 2012 sampling frame.

In descriptive analysis, we calculated the overall rates of minor and major LEAs per 100,000 U.S. population age ≥18 years. Information on the U.S. population for each study year was obtained from the U.S Census Bureau. We also calculated the percentage of diabetes-related admissions that resulted in a minor or major amputation by race/ethnicity, rural-urban category, and census region. For analysis of temporal trends in LEA rates, we used the Joinpoint Trend Analysis software, version 4.8.0.1 (23) to obtain annual percent changes (APC). The number of inflection points was set to zero so as to focus the analysis on overall linear trends of the time period of investigation. Second, we conducted separate logistic regressions to identify the racial/ethnic, rural/urban, and regional independent factors associated with minor and major amputations. We adjusted for sociodemographic factors (age, sex, insurance status, median household income for ZIP code), clinical factors (prior amputation, comorbidities), and admission year. Odds ratios (ORs) and CIs are presented. The $\alpha$-level for statistical significance was set at 0.05. Given the unusual uptick in minor and major LEA rates in 2017 across racial/ethnic, regional, and rural-urban categories, we conducted sensitivity analyses excluding year 2017 and compared the results with the main findings. STATA 14.1 (StataCorp, College Station, TX) was used for the regression analysis.

## RESULTS

### Patient Characteristics

From 2009 to 2017, there were 4,806,430 diabetes-related discharges in the U.S. (unweighted *n* = 979,417). Of these discharges, 8.8% (*n* = 86,171) and 2.7% (*n* = 26,542) involved a minor or major LEA, respectively. The mean (SEM) age for a diabetes discharge was 53.4 (0.05) years, and diabetes-related minor and major LEAs occurred at 60.1 (0.06) and 63.7 (0.10) years, respectively. A large proportion of the minor (72.1%, *n* = 62,080) and major (68%, *n* = 18,015) LEAs occurred among males, though they (males) constituted just over one-half of the diabetes-related admissions (54.5%, *n* = 532,820). Approximately 14.8% (*n* = 12,715) and 16.7% (*n* = 4,420) of patients who had a minor or major LEA had had a prior amputation.

### Overall Trends in Minor and Major LEAs

From 2009 to 2017, diabetes discharges increased by 17.9% from 212 per 100,000 adult population in 2009 to 250 per 100,000 adult population in 2017 (APC 1.1%, *P* = 0.10). The trends in minor and major LEAs are displayed in Fig. 1. Minor LEAs increased by 87.7% from 14.6 to 27.4 per 100,000 adult population between 2009 and 2017 (APC 6.2%, $P < 0.001$). Major amputations increased by 42.1% from 5.7 to 8.1 major amputations per 100,000 adult population (APC 2.7%, *P* = 0.10). Minor amputations increased among males and females during the study period (males, APC 4.8%, $P < 0.001$; females, APC 4.6%, $P < 0.001$), while no statistically significant changes were observed in major amputations (males, APC 1.4%, *P* = 0.09; females, APC = 1.4%, *P* = 0.25).

### Trends in Minor and Major LEAs by Race/Ethnicity, Rurality, and Region

From 2009 to 2017, minor LEAs increased significantly across all racial/ethnic, rural, and regional categories (Table 1). For race/ethnicity, minor amputations increased by 48.5% among Hispanic people (APC 5.3%, $P < 0.001$), 58.4% among White people (APC 4.4%, $P < 0.001$), 58.5% among Black people (APC 4.8%, $P < 0.001$), 94.1% among Asian people/Pacific Islanders (APC 7.8%, $P < 0.001$), 72% among Native Americans (APC 7.1%, $P < 0.001$), and

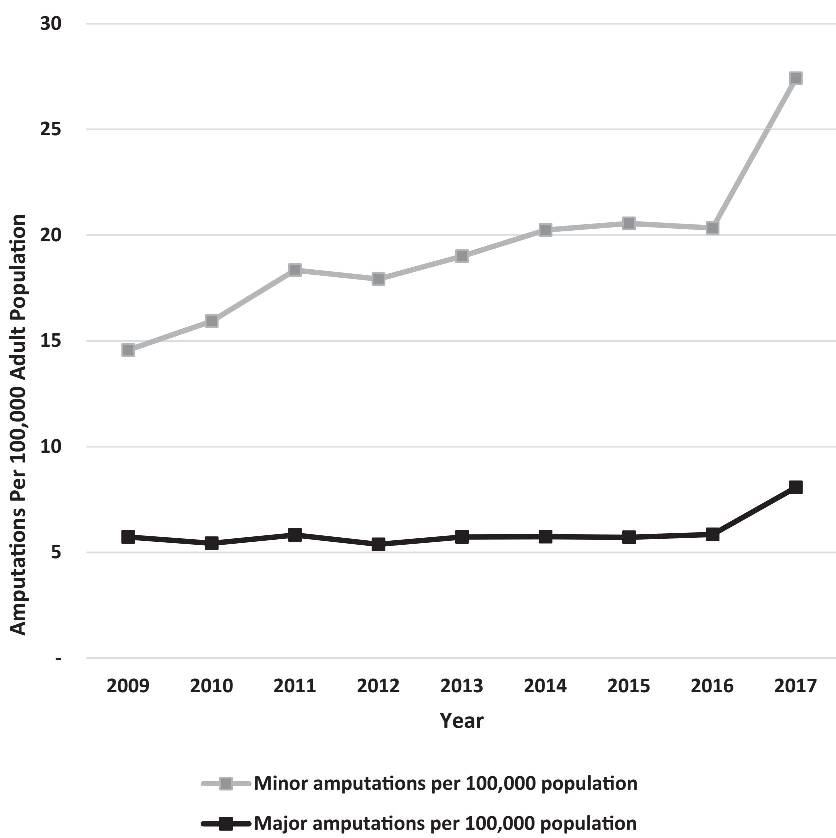


**Figure 1**—Minor and major amputations per 100,000 adult population, NIS, 2009–2017.

**Table 1—Percentage of patients admitted for diabetes with minor or major amputations (NIS, 2009–2017)**

| | 2009 | 2017 | Percentage change | APC (95% CI) | *P* |
|---|---|---|---|---|---|
| Minor LEA | | | | | |
| Sex | | | | | |
| Male | 9.19 | 3.93 | −57.24 | 4.8 (3.4, 6.3) | <0.001 |
| Female | 4.29 | 6.62 | 54.31 | 4.6 (3.0, 6.2) | <0.001 |
| Race | | | | | |
| White | 7.58 | 12.01 | 58.44 | 4.8 (3.3, 6.3) | <0.001 |
| Black | 4.96 | 7.86 | 58.47 | 4.4 (2.2, 6.6) | <0.001 |
| Hispanic | 8.36 | 12.41 | 48.46 | 5.3 (2.8, 6.8) | <0.001 |
| Asian or Pacific Islander | 4.95 | 9.61 | 94.14 | 7.8 (5.3, 10.4) | <0.001 |
| Native American | 8.03 | 13.81 | 71.98 | 7.1 (1.3, 13.3) | <0.001 |
| Other | 5.20 | 10.88 | 109.23 | 7.7 (3.4, 12.1) | <0.001 |
| Urban-rural continuum | | | | | |
| Large central metropolitan | 6.51 | 10.66 | 63.75 | 5.5 (3.7, 7.3) | <0.001 |
| Large fringe metropolitan | 7.39 | 11.27 | 52.50 | 4.7 (3.3, 6.2) | <0.001 |
| Medium metropolitan | 7.40 | 11.35 | 53.38 | 4.8 (3.2, 6.4) | <0.001 |
| Small metropolitan | 6.38 | 10.23 | 60.34 | 4.8 (3.3, 6.4) | <0.001 |
| Micropolitan | 6.88 | 11.08 | 61.05 | 4.9 (2.8, 7.1) | <0.001 |
| Noncore | 6.24 | 10.85 | 73.88 | 5.4 (3.1, 7.8) | <0.001 |
| Census region | | | | | |
| Northeast | 7.31 | 11.51 | 57.46 | 5.4 (3.3, 7.6) | <0.001 |
| Midwest | 6.15 | 10.61 | 72.52 | 5.3 (3.3, 7.4) | <0.001 |
| South | 7.03 | 10.71 | 52.35 | 4.6 (3.1, 6.1) | <0.001 |
| West | 6.84 | 11.29 | 65.06 | **5.6 (4.3, 7.0)** | <0.001 |
| Major LEA | | | | | |
| Sex | | | | | |
| Male | 3.33 | 3.93 | 18.01 | 1.4 (−0.3, 3.2) | 0.090 |
| Female | 2.00 | 2.31 | 15.5 | 1.4 (−1.2, 4.1) | 0.250 |
| Race | | | | | |
| White | 2.65 | 3.24 | 22.26 | 1.9 (0.1, 3.8) | <0.001 |
| Black | 2.53 | 3.06 | 20.95 | 1.2 (−1.1, 3.7) | 0.300 |
| Hispanic | 3.26 | 3.45 | 5.83 | 0.6 (−2.1, 3.4) | 0.600 |
| Asian or Pacific Islander | 2.50 | 2.99 | 19.60 | 1.6 (−5.3, 9.1) | 0.600 |
| Native American | 5.04 | 3.98 | −21.03 | 2.4 (−5.9, 11.4) | 0.500 |
| Other | 2.11 | 2.48 | 17.54 | 1.2 (−2.2, 4.7) | 0.400 |
| Urban-rural continuum | | | | | |
| Large central metropolitan | 2.50 | 2.86 | 14.40 | 1.1 (−1.8, 4.0) | 0.400 |
| Large fringe metropolitan | 2.44 | 2.89 | 18.44 | 1.8 (−0.8, 4.4) | 0.100 |
| Medium metropolitan | 2.98 | 3.372 | 13.15 | 0.6 (−1.3, 2.6) | 0.500 |
| Small metropolitan | 2.58 | 3.72 | 44.19 | **2.6 (0.1, 5.2)** | <0.001 |
| Micropolitan | 3.41 | 3.77 | 10.56 | 1.7 (−1.7, 5.3) | 0.300 |
| Noncore | 3.32 | 4.31 | 29.82 | **2.9 (1.1, 4.7)** | <0.001 |
| Census region | | | | | |
| Northeast | 2.33 | 2.89 | 24.03 | 1.6 (−1.4, 4.8) | 0.200 |
| Midwest | 2.24 | 3.22 | 43.75 | **4.0 (1.9, 6.1)** | <0.001 |
| South | 2.99 | 3.50 | 17.06 | 1.1 (−0.9, 3.2) | 0.200 |
| West | 2.95 | 2.86 | −3.05 | −0.1 (−2.1, 2.0) | 0.900 |

Boldface type indicates statistically significant APC.

109% among those who identified their race as "other" (APC 7.7%, $P < 0.001$) (Table 1 and Fig. 2). Pertaining to rurality, minor LEAs increased by 63.8% among residents of large central metropolitan areas (APC 5.5%, $P < 0.001$), 61.1% among micropolitan residents (APC 4.9%, $P < 0.001$), and 73.9% among non-core residents (APC 5.4%, $P < 0.001$). For census regions, minor LEAs increased by 57.5% in the Northeast (APC 5.4%, $P < 0.001$), 72.5% in the Midwest (APC 5.3%, $P < 0.001$), 52% in the South (APC 4.6%, $P < 0.001$), and 65.1% in the West (APC 5.6%, $P < 0.001$) (Table 1).

For major LEAs, only the APC values of White people and residents of the Midwest, non-core, and small metropolitan areas were statistically significant (Table 1). Major LEAs increased by 22.3% among White people (APC 1.9%, $P < 0.001$) and by 44.2% and 29.8% among residents of small metropolitan (APC 2.6%, $P < 0.001$) and non-core areas (APC 2.9%, $P < 0.001$), respectively. Like the sharp increase in minor LEAs, those in the Midwest experienced a 44% jump in major LEA rates (APC 4.0%, $P < 0.001$). The APC for Native Americans was not statistically significant (APC 2.4%, $P = 0.50$), although there was a 21% decrease in major LEA rates in 2017 in comparison with 2009.

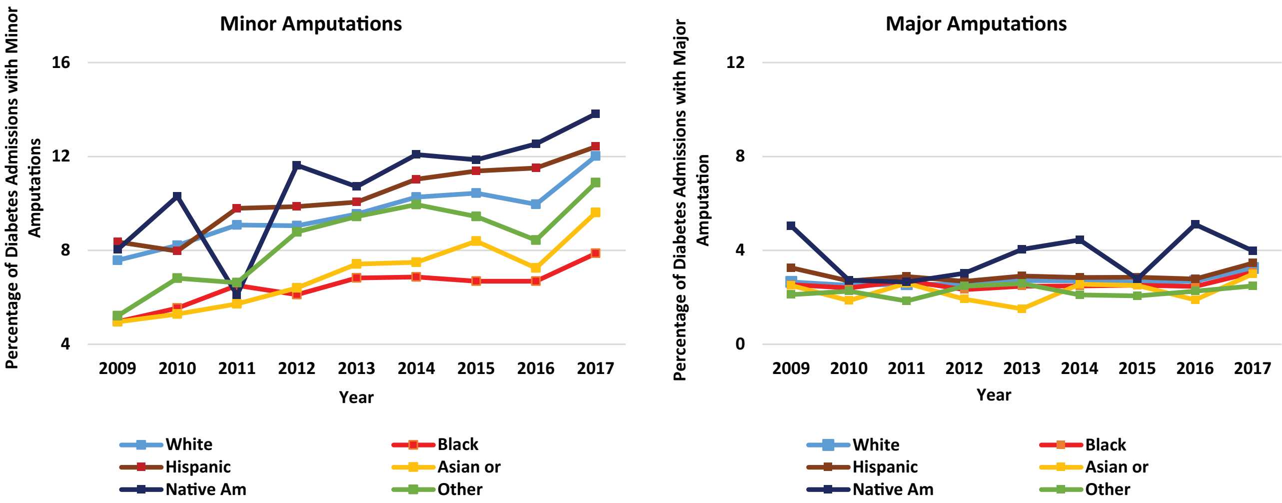


**Figure 2**—Percentage of patients admitted for diabetes with minor and major amputations by race/ethnicity, NIS, 2009–2017. Asian or, Asian or Pacific Islander; Native Am, Native American.



The major-to-minor LEA ratios declined across all racial/ethnic categories between 2009 and 2017. However, the most drastic decrease was observed among Native Americans (2009 major-to-minor amputation ratio, 0.63, and 2017, 0.29). For more details on the major–to–minor amputation ratios by race/ethnicity, see Appendix 3a and 3b.

### Factors Associated With a Minor Amputation

After adjustment for sociodemographic and clinical characteristics, males (OR 2.14; 95% CI 2.11, 2.18), Native Americans (OR 1.26; 95% CI 1.167, 1.36), and residents of medium metropolitan areas (OR 1.05; 95% CI 1.03, 1.07) and the South census region (OR 1.02; 95% CI 1.002, 1.05) were more likely to have a minor amputation compared with females, Whites, and residents of large central metropolitan areas and the North census region, respectively (Table 2). The odds of a minor LEA also increased linearly from 2009 to 2017.

### Factors Associated With a Major Amputation

Males were almost twice as likely to have a major amputation compared with females (OR 1.82; 95% CI 1.77, 1.87). Blacks (OR 1.12; 95% CI 1.08, 1.16), Hispanics (OR 1.24; 95% CI 1.19, 1.29), and Native Americans (OR 1.32; 95% CI 1.16, 1.50) were more likely to experience a major amputation compared with Whites (Table 2). The highest odds were observed among Native Americans. For rurality, the odds of major amputations increased along the urban-rural continuum. Notably, residents of micropolitan (OR 1.50; 95% CI 1.48, 1.57) and non-core areas (OR 1.56; 95% CI 1.48, 1.65) had higher odds of having a major amputation compared with those in large central metropolitan areas. Pertaining to census regions, the odds of a major amputation were highest in the south (OR 1.37; 95% CI 1.31, 1.42), followed by the West (OR 1.27; 95% CI 1.21, 1.33) and Midwest (OR 1.12; 95% CI 1.07, 1.17) census regions. The odds of a major LEA were higher in 2017 (OR 1.18; 95% CI 1.1, 1.24) compared with 2009 but lower in the intervening years. To ensure that our findings were robust to the noted increases in diabetes discharges in 2017, we conducted sensitivity analysis whereby patients discharged from that year were excluded. The findings pertaining to minor LEAs remained unchanged. Moreover, the findings on what predicts major LEAs remained unchanged.

## CONCLUSIONS

The primary finding from this study is that the rates of minor LEAs during diabetes-related hospitalizations increased across all racial/ethnic, rural/urban, and census region categories between 2009 and 2017. We show that the increase in minor LEAs was driven by those of identifying as Native Americans, Asians/Pacific Islanders, other race and residents of non-core areas and the West census region.

Second, except for Whites and residents of the Midwest, non-core, and small metropolitan areas who experienced significant increases in major LEA rates, the rates of major LEAs remained stable over time across the categories examined. Overall, these findings are consistent with those of Geiss et al. (6), who reported increasing minor LEA rates and decreasing major LEA rates between 2009 and 2015. Third, after adjustment for sociodemographic and clinical characteristics, being Native American or Hispanic was independently associated with having a minor or major LEA during a diabetes-related admission. Though Blacks were less likely to have a minor amputation, they were more likely to experience a major LEA compared with Whites. The odds of a major LEA increased with rurality and were also higher among residents of the South census region compared with those of the Northeast. Minor LEAs increased among males and females, which was reflective of the overall upward trend in minor LEAs. However, no statistically significant increase in major LEAs was observed among males and females. Regression findings showed that males continue to be at a higher risk of both minor and major LEAs, though they constitute just over half of the diabetes-related admissions. Our finding of increased LEA risk among males is consistent with prior literature. One explanation for the correlation between male sex and

**Table 2—Odds of a minor or major amputation during a diabetes-related hospitalization (NIS 2009–2017)**

| | Minor amputation | Major amputation |
|---|---|---|
| Race/ethnicity | | |
| White | 1.000 | 1.000 |
| Black | 0.707*** (0.692, 0.722) | 1.121*** (1.083, 1.161) |
| Hispanic | 1.110*** (1.084, 1.136) | 1.237*** (1.185, 1.291) |
| Asian or Pacific Islander | 0.684*** (0.639, 0.732) | 0.825** (0.731, 0.932) |
| Native American | 1.257*** (1.166, 1.356) | 1.322*** (1.163, 1.504) |
| Other | 0.872*** (0.831, 0.916) | 0.971 (0.885, 1.066) |
| Missing | 0.953** (0.920, 0.987) | 1.091** (1.027, 1.158) |
| Urban-rural classification | | |
| Large central metropolitan | 1.000 | 1.000 |
| Large fringe metropolitan | 1.000 (0.979, 1.022) | 1.055* (1.012, 1.100) |
| Medium metropolitan | 1.048*** (1.025, 1.071) | 1.354*** (1.302, 1.408) |
| Small metropolitan | 0.964* (0.936, 0.993) | 1.361*** (1.293, 1.431) |
| Micropolitan | 1.013 (0.984, 1.042) | 1.499*** (1.428, 1.574) |
| Noncore | 0.982 (0.950, 1.015) | 1.559*** (1.476, 1.645) |
| Census region | | |
| Northeast | 1.000 | 1.000 |
| Midwest | 0.935*** (0.912, 0.958) | 1.118*** (1.066, 1.171) |
| South | 1.024* (1.002, 1.046) | 1.365*** (1.311, 1.422) |
| West | 0.963** (0.939, 0.987) | 1.267*** (1.208, 1.329) |
| Sex | | |
| Male | 2.142*** (2.107, 2.177) | 1.821*** (1.770, 1.874) |
| Female | 1.000 | 1.000 |
| Age category (years) | | |
| 18–44 | 1.000 (1.000, 1.000) | 1.000 (1.000, 1.000) |
| 45–64 | 3.867*** (3.776, 3.961) | 4.765*** (4.515, 5.029) |
| 65–74 | 4.418*** (4.288, 4.551) | 6.163*** (5.801, 6.548) |
| ≥75 | 3.387*** (3.280, 3.497) | 6.439*** (6.054, 6.849) |
| Primary payer | | |
| Medicare | 0.884*** (0.866, 0.903) | 1.487*** (1.427, 1.549) |
| Medicaid | 0.836*** (0.815, 0.856) | 1.092*** (1.039, 1.149) |
| Private | 1.000 | 1.000 |
| Self-pay/no charge | 0.882*** (0.856, 0.910) | 0.604*** (0.560, 0.652) |
| Other | 0.875*** (0.835, 0.916) | 0.948 (0.862, 1.044) |
| Median household income | | |
| $1–$38,999 | 0.982 (0.957, 1.007) | 1.044 (0.995, 1.095) |
| $39,000–$47,000 | 0.993 (0.967, 1.018) | 1.057* (1.007, 1.109) |
| $48,000–$62,999 | 1.019 (0.994, 1.045) | 1.037 (0.988, 1.088) |
| ≥$63,000 | 1.000 (1.000, 1.000) | 1.000 (1.000, 1.000) |
| Prior amputation | | |
| No | 1.000 (1.000, 1.000) | 1.000 (1.000, 1.000) |
| Yes | 2.623*** (2.565, 2.683) | 3.087*** (2.976, 3.203) |
| Year | | |
| 2009 | 1.000 (1.000, 1.000) | 1.000 (1.000, 1.000) |
| 2010 | 1.073*** (1.036, 1.112) | 0.915** (0.863, 0.970) |
| 2011 | 1.205*** (1.164, 1.247) | 0.951 (0.898, 1.006) |
| 2012 | 1.238*** (1.196, 1.282) | 0.933* (0.880, 0.990) |
| 2013 | 1.314*** (1.270, 1.360) | 0.983 (0.927, 1.042) |
| 2014 | 1.398*** (1.351, 1.447) | 0.979 (0.924, 1.038) |
| 2015 | 1.415*** (1.368, 1.464) | 0.977 (0.922, 1.036) |
| 2016 | 1.377*** (1.331, 1.424) | 0.978 (0.923, 1.036) |
| 2017 | 1.625*** (1.574, 1.679) | 1.180 (1.118, 1.245)*** |

Data are OR (95% CI). *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

increased risk of LEA is that men are more likely to have some of the independent predictors for LEA, such as diabetic foot ulceration, peripheral arterial disease, cigarette use, and peripheral neuropathy (24–26). Another explanation for sex differences in the risk of LEA might be the inferior level of foot care among male patients with diabetes compared with female counterparts, resulting in a higher proportion of amputations among them (27).

From a public health perspective, amputations, regardless of type, exert socioeconomic and functional limitations on patients and represent a failure of early prevention through regulation of modifiable risk factors (28). However, from a clinical standpoint, major LEAs can be more functionally devastating than minor ones and have been shown to be associated with increased morbidity and mortality due to increased body mass loss, lack of ambulation, and cardiovascular complications (29). Moreover, higher levels of depression (30) and reduced health-related quality of life have been reported with major amputations, particularly among nonambulatory patients (31). Hence, in some cases, a minor amputation may be considered a success for a patient.

Our findings of increased LEA risk among Hispanics, Blacks, and Native Americans are consistent with those of prior studies showing disproportionately higher rates of LEAs and other diabetes-related complications among racial and ethnic minority populations (8,9,32–34). However, the underlying causes of the sharp rise in minor LEA rates among Asian Americans are unknown. Future studies should explore this phenomenon.

Among Native Americans, we observed a significant increase in minor LEAs and a non–statistically significant increase in major LEAs over time. Further analysis showed that the ratio of major to minor amputations, a measure of the quality of diabetic foot care (35), decreased within this group over the study period. Though we did not find other peer-reviewed literature with investigation of this trend, it is known that programs from the Indian Health Service, particularly the Special Diabetes Program for Indians, have helped to decrease the onset and complications of diabetes among Native Americans (36). Through diabetes surveillance systems and a vast network of diabetes prevention and treatment systems, the Indian Health Service was able to report an 8% reduction in hemoglobin $A_{1c}$ ($HbA_{1c}$) levels between 1997 and 2015 among Native Americans (35). Thus, the declining major–to–minor LEA ratios may be due to early diagnosis of diabetes and improved diabetes management and education systems within this population.

Given the devastating effects of major LEAs, the increasing rates of minor LEAs and the declining major–to–minor amputation ratios may be considered a positive outcome for this group and are indicative of improving care for Native Americans. It has also been suggested that in comparison with physician treatment of other racial/ethnic groups, physicians are more likely to pursue amputations rather than attempt revascularization within this group (37).

Rurality was also a major driving factor for major LEAs. This finding is consistent with prior research documenting rural disparities in diabetes morbidity, mortality, and complications from the disease (12,14,16). Higher risk of adverse outcomes related to diabetes among rural residents is likely a consequence of limited access to preventative and specialty health care due to geographic isolation, chronic provider shortages, high rates of uninsured persons, and limited availability of public transportation in rural areas. Furthermore, rural residents are more likely to be unemployed, have less educational attainment, and have lower median household incomes than their urban-dwelling counterparts. As a result, rural residents are more likely to delay or forgo preventative care services that could reduce the risk of an LEA or other severe diabetes complications, including $HbA_{1c}$ testing, annual comprehensive foot examinations, nutrition education, and diabetes self-monitoring programs (11,38). Over the past several decades, telehealth and other Web-based interventions have emerged as promising approaches for improving access to diabetes care, education, and management in rural areas. Further development of easily accessible comprehensive rural diabetes care should be a major focus of rural health policy makers.

Our study also uncovered the rise in major LEAs in the Midwest. Reasons for this are unclear, particularly given that the Midwest states are outside of the diabetes belt and have historically had lower diabetes prevalence rates (39), as well as declining diabetes mortality rates, compared with the South census region (14). However, more recent analysis of the NIS showed that non-core residents of the Midwest and South census regions were at higher risk of being hospitalized following a diabetes-related emergency room visit (40). These findings are even more concerning as a few states in the Midwest have not expanded Medicaid under the Affordable Care Act (41), and previous research has shown that Medicaid-expansion states saw improvements in diabetes management rates (42).

### Limitations

Our study has a few important limitations. First, this is a retrospective observational study and is subject to the standard biases of observational studies, such as confounding and selection bias. Second, large administrative databases such as the NIS are susceptible to errors in the coding of diseases or procedures and missing data. Additionally, because the unit of analysis in the NIS is based on hospital admissions, not unique patients, we could not account for multiple hospital admissions of a single patient during a calendar year. Thus, it is possible that a single patient could have been represented more than once in our study. Fourth, the NIS does not include information on procedures performed during an outpatient visit. Thus, our study does not capture the minor amputations that occur in ambulatory settings. Finally, we did not exclude from our analysis discharge records of individuals who were admitted with a primary diagnosis of diabetes and underwent a major or minor LEA but died during hospitalization, and this may have affected our calculation of amputation rates across different race/ethnicities. Though mortality was outside the scope of this study, it remains an important area for future research.

### Conclusion

With use of data from more recent years, this study contributes to the literature outlining the rising incidence of minor LEA among U.S. adults who are hospitalized for diabetes (6). In addition to the well-known disparities in LEAs affecting Blacks, Hispanics, and Native Americans (8), we draw attention to the rising minor LEA rates among Asians/Pacific Islanders and among those who identify their race as "other." Geographically, we also highlight the rising risk of major LEA along the urban-rural continuum and among patients with diabetes hospitalized in the Midwest. Given the important consequences of amputation for mobility, employment, mental health status, and other health outcomes, targeted public health interventions and additional investment emphasizing diabetes education and management are needed for these populations. Renewed efforts are needed to further elucidate the underlying mechanisms contributing to the recent rise in and increased risk of diabetes-related lower-limb amputations in geographically underserved and minority groups.

**Funding.** This study was supported by the Federal Office of Rural Health Policy (FORHP), Health Resources and Services Administration (HRSA), U.S. Department of Health and Human Services (HHS), under cooperative agreement no. U1CRH30040.

The information, conclusions, and opinions expressed in this article are those of the authors and no endorsement by FORHP, HRSA, or HHS is intended or should be inferred.

**Duality of Interest.** No potential conflicts of interest relevant to this article were reported.

**Author Contributions.** M.A., K.P., and J.B. conceptualized the study design, conducted and interpreted the analyses, and drafted the manuscript. A.L.F.C., J.L., T.C., and A.O.F. interpreted the analyses and revised the article. All authors approved the final version of the article. M.A. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

### References

1. Centers for Disease Control and Prevention. *National Diabetes Statistics Report, 2017*. Atlanta, GA, Centers for Disease Control and Prevention, U.S. Department of Health and Human Services, 2017
2. Franklin H, Rajan M, Tseng C-L, Pogach L, Sinha A, Mph M. Cost of lower-limb amputation in U.S. veterans with diabetes using health services data in fiscal years 2004 and 2010. J Rehabil Res Dev 2014;51:1325–1330
3. Wu SC, Driver VR, Wrobel JS, Armstrong DG. Foot ulcers in the diabetic patient, prevention and treatment. Vasc Health Risk Manag 2007;3:65–76
4. Margolis DJ, Malay DS, Hoffstad OJ, et al. Economic Burden of Diabetic Foot Ulcers and Amputations: Data Points #3, 2011. Rockville, MD, Agency for Healthcare Research and Quality (US). Accessed 8 December 2020. Available from https://www.ncbi.nlm.nih.gov/books/NBK65152/
5. Dillingham TR, Pezzin LE, Shore AD. Reamputation, mortality, and health care costs among persons with dysvascular lower-limb amputations. Arch Phys Med Rehabil 2005;86: 480–486
6. Geiss LS, Li Y, Hora I, Albright A, Rolka D, Gregg EW. Resurgence of diabetes-related nontraumatic lower-extremity amputation in the young and middle-aged adult U.S. population. Diabetes Care 2019;42:50–54
7. Li Y, Burrows NR, Gregg EW, Albright A, Geiss LS. Declining rates of hospitalization for nontraumatic lower-extremity amputation in the

diabetic population aged 40 years or older: U.S., 1988–2008. Diabetes Care 2012;35:273–277
8. Tan T-W, Shih C-D, Concha-Moore KC, et al. Disparities in outcomes of patients admitted with diabetic foot infections. PLoS One 2019;14:e0211481
9. Garcia M, Hernandez B, Ellington TG, et al. A lack of decline in major nontraumatic amputations in Texas: contemporary trends, risk factor associations, and impact of revascularization. Diabetes Care 2019;42:1061–1066
10. Suckow BD, Newhall KA, Bekelis K, et al. Hemoglobin A1c testing and amputation rates in black, Hispanic, and white Medicare patients. Ann Vasc Surg 2016;36:208–217
11. Towne SD, Bolin J, Ferdinand A, Nicklett EJ, Smith ML, Ory MG. Assessing diabetes and factors associated with foregoing medical care among persons with diabetes: disparities facing American Indian/Alaska Native, Black, Hispanic, low income, and Southern adults in the U.S. (2011-2015). Int J Environ Res Public Health 2017;14:464
12. Ferdinand AO, Akinlotan MA, Callaghan T, Towne SD Jr, Bolin J. Diabetes-related hospital mortality in the U.S.: a pooled cross-sectional study of the National Inpatient Sample. J Diabetes Complications 2019;33:350–355
13. Margolis DJ, Hoffstad O, Nafash J, et al. Location, location, location: geographic clustering of lower-extremity amputation among Medicare beneficiaries with diabetes. Diabetes Care 2011;34:2363–2367
14. Callaghan T, Ferdinand AO, Akinlotan MA, Towne SD Jr, Bolin J. The changing landscape of diabetes mortality in the United States across region and rurality, 1999-2016. J Rural Health 2020;36:410–415
15. Yin H, Radican L, Kong SX. A study of regional variation in the inpatient cost of lower extremity amputation among patients with diabetes in the United States. J Med Econ 2013; 16:820–827
16. Cao J, Sharath SE, Zamani N, Barshes NR. Health care resource distribution of Texas counties with high rates of leg amputations. J Surg Res 2019;243:213–219
17. Skrepnek GH, Mills JL Sr, Armstrong DG. A diabetic emergency one million feet long: disparities and burdens of illness among diabetic foot ulcer cases within emergency departments in the United States, 2006–2010. PLoS One 2015;10:e0134914
18. Tan T-W, 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 2020;8:e001328
19. Agency for Healthcare Research and Quality. Overview of the National (Nationwide) Inpatient Sample (NIS), 2018. Accessed 14 May 2020. Available from www.hcup-us.ahrq.gov/nisoverview.jsp
20. Agency for Healthcare Research and Quality. Clinical Classifications Software (CCS) for ICD-9-CM, 2017. Available from www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp. Accessed 14 May 2020
21. National Center for Health Statistics. NCHS Urban-Rural Classification Scheme for Counties, 2017. Accessed 1 December 2020. Available from https://www.cdc.gov/nchs/data_access/urban_rural.htm
22. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 1987;40:373–383
23. Kim H-J, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. Stat Med 2000;19: 335–351
24. Kumar A, Mash B, Rupesinghe G. Peripheral arterial disease - high prevalence in rural black South Africans. S Afr Med J 2007;97:285–288
25. Kiziltan ME, Gunduz A, Kiziltan G, Akalin MA, Uzun N. Peripheral neuropathy in patients with diabetic foot ulcers: clinical and nerve conduction study. J Neurol Sci 2007;258:75–79
26. Tan YY, Gast G-CM, van der Schouw YT. Gender differences in risk factors for coronary heart disease. Maturitas 2010;65:149–160
27. Laclé A, Valero-Juan LF. Diabetes-related lower-extremity amputation incidence and risk factors: a prospective seven-year study in Costa Rica. Rev Panam Salud Publica 2012;32:192–198
28. Tuomilehto J, Schwarz PEH. Preventing diabetes: early versus late preventive interventions. Diabetes Care 2016;39(Suppl. 2):S115–S120
29. Thorud JC, Plemmons B, Buckley CJ, Shibuya N, Jupiter DC. Mortality after nontraumatic major amputation among patients with diabetes and peripheral vascular disease: a systematic review. J Foot Ankle Surg 2016;55:591–599
30. Cascini S, Agabiti N, Davoli M, et al. Survival and factors predicting mortality after major and minor lower-extremity amputations among patients with diabetes: a population-based study using health information systems. BMJ Open Diabetes Res Care 2020;8:e001355
31. Wukich DK, Ahn J, Raspovic KM, La Fontaine J, Lavery LA. Improved quality of life after transtibial amputation in patients with diabetes-related foot complications. Int J Low Extrem Wounds 2017;16:114–121
32. Young BA, Maynard C, Reiber G, Boyko EJ. Effects of ethnicity and nephropathy on lower-extremity amputation risk among diabetic veterans. Diabetes Care 2003;26:495–501
33. Mier N, Ory M, Zhan D, Villarreal E, Alen M, Bolin J. Ethnic and health correlates of diabetes-related amputations at the Texas-Mexico border. Rev Panam Salud Publica 2010;28:214–220
34. Pandit V, Nelson P, Kempe K, et al. Racial and ethnic disparities in lower extremity amputation: assessing the role of frailty in older adults. Surgery 2020;168:1075–1078
35. Wrobel JS, Robbins J, Armstrong DG. The high-low amputation ratio: a deeper insight into diabetic foot care? J Foot Ankle Surg 2006;45:375–379
36. Indian Health Service. Special Diabetes Program for Indians | Fact Sheets. Newsroom. 2013. Accessed 5 November 2020. Available from https://www.ihs.gov/newsroom/factsheets/diabetes/
37. Rizzo JA, Chen J, Laurich C, et al. Racial disparities in PAD-related amputation rates among Native Americans and non-Hispanic whites: an HCUP analysis. J Health Care Poor Underserved 2018;29:782–800
38. Krishna S, Gillespie KN, McBride TM. Diabetes burden and access to preventive care in the rural United States. J Rural Health 2010;26:3–11
39. Shrestha SS, Kirtland KA, Thompson TJ, Barker L, Gregg EW, Geiss L. Spatial clusters of county-level diagnosed diabetes and associated risk factors in the United States. Open Diabetes J 2012;5:29–37
40. Ferdinand AO, Akinlotan MA, Callaghan T, Towne SD Jr, Bolin JN. Factors affecting the likelihood of a hospitalization following a diabetes-related emergency department visit: a regional and urban-rural analysis. J Diabetes 2020;12:686–696
41. Kaiser Family Foundation. Status of State Medicaid Expansion Decisions: Interactive Map [Internet]. KFF. 2020. Accessed 14 December 2020. Available from https://www.kff.org/medicaid/issue-brief/status-of-state-medicaid-expansion-decisions-interactive-map/
42. Lee J, Callaghan T, Ory M, Zhao H, Bolin JN. The impact of Medicaid expansion on diabetes management. Diabetes Care 2020; 43:1094–1101