



Diabetes-related hospital mortality in the U.S.: A pooled cross-sectional study of the National Inpatient Sample

Alva O. Ferdinand^{a,b,*}, Marvellous A. Akinlotan^{a,b}, Timothy Callaghan^{a,b}, Samuel D. Towne Jr^{b,c,d}, Jane Bolin^{a,b}

^a Department of Health Policy and Management, School of Public Health, Texas A&M University, College Station, TX, United States of America

^b Southwest Rural Health Research Center, School of Public Health, Texas A&M University, College Station, TX, United States of America

^c Department of Health Management and Informatics, University of Central Florida, Orlando, FL, United States of America

^d Disability, Aging, and Technology Cluster, University of Central Florida, Orlando, FL, United States of America

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ABSTRACT

Aims: Despite advancements in the diagnosis and treatment of diabetes in the U.S., place-based disparities still exist. The purpose of this study is to determine place-based and other individual-level variations in diabetes-related hospital deaths.

Methods: A pooled cross-sectional study of the 2009–2015 National Inpatient Sample was conducted to examine the odds of a diabetes-related hospital death. The main predictors were rurality and census region. Individual-level socio-demographic factors were also examined.

Results: Approximately 1.5% (n = 147,069) of diabetes-related hospitalizations resulted in death. In multivariable analysis, the odds of diabetes-related hospital deaths increased across the urban-rural continuum, except for large fringe metropolitan areas, with the highest odds of such deaths occurring among residents of micropolitan (OR = 1.16, 95% C.I. = 1.14, 1.18) and noncore areas (OR = 1.21, 95% C.I. = 1.19, 1.24). Compared to residents of the Northeast, residents in the South, West and Midwest regions were significantly more likely to experience a diabetes-related hospital death. Asian or Pacific Islanders, Medicaid-covered patients and the uninsured were also more likely to die during a diabetes-related hospitalization.

Conclusions: Place-based disparities in diabetes-related hospital deaths exist. Targeted focus should be placed on the control of diabetic complications in the South, West and Midwest census regions, and among rural residents.

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1. Introduction

Despite advancements in its treatment over time and its designation as an ambulatory care sensitive condition, diabetes mellitus continues to be the seventh leading cause of death in the United States (U.S.).¹ The economic burden associated with diabetes is profound. According to the American Diabetes Association, the total estimated cost of diabetes in 2017 was \$327 billion, with \$90 billion attributed to lost productivity, and \$237 billion attributed to direct medical costs.² Previous research has indicated that some individuals living with the disease are unaware of their diagnosis,³ and that some individuals experience periods of foregone diabetes-related care.⁴ The likelihood of foregone diabetes-related care has been shown to be higher among those with low incomes, identifying with a racial or ethnic minority group, and residing in the U.S. South.⁴

A robust literature has emerged regarding the challenges that persons with diabetes face in the U.S. as it relates to securing appropriate care. These challenges include provider shortages,⁵ un-insurance,⁶ interruptions in insurance coverage,^{7–9} patient navigation,¹⁰ care that is not culturally sensitive,¹¹ and coverage for and adherence to medications.¹² However, the burden of diabetes and the challenges associated with the disease are not equally distributed throughout the U.S. population. In a survey of rural health stakeholders, diabetes was identified as being in the top three health challenges in rural America.¹³ A few state-specific studies have noted that rural residents bear a higher burden of diabetes than their urban counterparts,^{14–16} and this is especially problematic because of the significant barriers that rural residents face in their attempts to properly manage chronic conditions.^{17,18} These barriers include persistent limited access to outpatient specialty care.¹⁹ In the face of limited access to care, rural residents have been shown to delay seeking care, seek care at more advanced stages of disease, and obtain hospital-based care.²⁰ However, hospital-based care is often not ideal for ambulatory care sensitive conditions such as diabetes in part because of the associated medical costs and the lack of continuity of care. Previous research has demonstrated that rural residents living with diabetes have lower rates of a follow-up physician visit within thirty days of a

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* Corresponding author at: Texas A&M University, Department of Health Policy & Management, 132 Administration Building, MS 1266, College Station, TX 77843-1266, United States of America.

E-mail address: aferdinand@tamu.edu (A.O. Ferdinand).

hospitalization.²¹ It has also been noted that rural residents sometimes bypass rural hospitals to seek emergency care in larger, and more urban hospitals.²² Taken together, the literature suggests that geographic location can create significant barriers for diabetes care with critical implications for clinical outcomes among rural residents, most notably patient mortality.

Several studies have explored diabetes-related mortality and variations in its occurrence throughout the U.S. Researchers have noted that this specific kind of mortality has significantly decreased over time.²³ Critically however, diabetes continues to be among the top ten causes of death in the U.S. and the ranking is even more pronounced when race and ethnicity are considered. According to the National Center for Health Statistics, as of 2016, diabetes ranked as the fourth most common cause of death for American Indians or Alaska Native individuals, and fifth for individuals of Hispanic, Black, and Asian or Pacific Islander descent.¹ Disproportionate race and ethnicity-based diabetes mortality findings have been reported in other literature as well.^{24–26} However, very little is known about variations in diabetes-related mortality across the four U.S. census regions. Moreover, the extent to which individual-level and place-based variations play a role in diabetes-related mortality occurring in hospitals is also under-studied.

Therefore, the purpose of this study is to critically examine place-based diabetes mortality in the U.S., particularly by investigating variations in hospital deaths based on patients' residence, i.e. urban or non-urban residence, and census region. Building on previous work, we also examine the role of insurance status, and race and ethnicity, among other factors on diabetes-related hospital mortality. Given the prevalence of uncontrolled diabetes, the use of hospital care to treat the disease, and the high costs associated with such care, it is important to identify segments of the population that are at increased risk of a diabetes-related hospital death. Overall, this study will be of interest to healthcare organizations and providers, insurers, community health workers, public health personnel, policymakers, and other stakeholders interested in decreasing the diabetes mortality burden in the U.S.

2. Material and methods

2.1. Data

Data for this study were obtained from the National Inpatient Sample (NIS), which is developed by the Healthcare Cost and Utilization Project (HCUP) and made available by the Agency for Healthcare Research and Quality (AHRQ). The NIS is the largest all-payer inpatient database in the U.S. and contains both clinical and resource use information for each discharge record. We used data from the years 2009 to September 2015 to conduct this study. Hospitals transitioned from International Classification of Diseases, Clinical Modification [ICD-9-CM] codes to ICD-10-CM/PCS codes (International Classification of Diseases, 10th Revision, Clinical Modification/Procedure Coding System) in October 2015. Hence, for year 2015, we restricted our data to the first nine months to ensure consistency in our diagnostic inclusion criteria across the years in our study. Prior to 2012, the NIS was a 20% stratified sample of hospitals. However, in 2012, to make the sample more nationally representative, the NIS was redesigned into a 20% stratified sample of all discharges from hospitals participating in HCUP.²⁷ While the NIS can be used to provide national estimates using sampling weights, our goal was to examine regional differences in the predictors of diabetes-related hospital mortality. As such, consistent with other studies that used the NIS to examine regional variations in hospital outcomes,^{28,29} we used crude numbers from the sample to assess the significant predictors of diabetes-related hospital mortality.

2.2. Study sample and dependent variable

Diabetes-related hospitalizations were defined using AHRQ's Clinical Classification Software (CCS) codes. The CCS codes were developed by

the AHRQ and converts over 14,000 ICD-9-CM codes into 260 clinically meaningful categories.³⁰ Discharges that were diabetes-related were identified based on the presence of CCS codes 49 (diabetes) or 50 (diabetes with complications) in the principal or secondary diagnostic categories. To increase sample sensitivity, we limited the identification to the principal and the first nine secondary diagnosis codes. These codes capture all sampled cases of diabetes (type 1 and type 2), including insulin-dependent, non-insulin dependent, malnutrition-related, and other types of diabetes-related discharges. Our outcome variable was diabetes-related death during hospitalization and was coded dichotomously as 1 "died during hospitalization" versus 0 "did not die during hospitalization."

2.3. Independent variables

Our main independent variables were rurality of patient's residence, and census region in which the admitting hospital was located. The hospital census region was included to compare outcomes geographically across regions. The patient's residential location was critical to our analysis because it served as a contextual measure of socio-economic status and access to care healthcare resources, and enabled us to examine the likelihood of death across the rural-urban continuum. The NIS contains information on six levels of rurality, which is determined using the 2013 National Center for Health Statistics (NCHS) Urban-Rural classification scheme.³¹ These include: metropolitan areas 1) large central metropolitan; 2) large fringe metropolitan; 3) medium metropolitan; 4) small metropolitan; and non-metropolitan areas 5) micropolitan; and 6) noncore or rural-remote areas.

We also analyzed the likelihood of a diabetes-related death during hospitalization by other socio-demographic variables (gender, age, race/ethnicity, primary payer, and survey year) and adjusted for comorbidities using the Charlson Comorbidity Index. Gender was coded as male/female. All age groups were considered, and age was coded as 0–17, 18–29, 30–44, 45–54, 55–64, 65–74, 75 and older. Race and ethnicity were coded as White, Black, Hispanic, Asian or Pacific Islander, Native American, and other. One of the limitations of the NIS dataset is the high proportion of missing data values for the race variable, which is due to some sampled hospitals not providing information on race. In our analytic sample, the race variable had missing data values on 757,227 discharge records. Therefore, we included 'missing' as a category for the race variable, which while restrictive in terms of interpreting race for these observations, allows us to use a larger sample when interpreting other variables (e.g., in bivariate analyses). Primary payer source was coded as private, Medicare, Medicaid, self-pay, and other, which included uncompensated care.

2.4. Statistical analyses

Descriptive statistics were generated to estimate the numbers diabetes-related hospitalizations and deaths. Logistic regressions were used to assess the relationships between the independent variables and the diabetes-related hospital mortality, controlling for year and population estimates. Thereafter, we used logistic regression to estimate the odds of diabetes-related hospital mortality by rurality, census region, and other covariates. Further, we conducted separate logistic regressions to examine the influence of rurality on diabetes-related hospital mortality across all four census regions. All analyses were done in STATA 14.1 (StataCorp, College Station, TX).

2.5. Role of the funding source

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 #U1CRH30040. The funding source was interested in a contemporary view of the diabetes burden in the United States,

particularly across the urban-rural continuum. It left the design, conduct and reporting of the findings primarily to the researchers.

3. Results

In the HCUP NIS, a total of 9,515,894 persons were admitted between January 2009 and September 2015 with a diabetes-related diagnosis. About 1.5% ($n = 147,069$) of the diabetes-related hospitalizations resulted in death, which is equivalent to an average of 21,009 diabetes-related hospital deaths per year (Table 1). During the same time period, diabetes-related hospitalizations decreased by 27%, while diabetes-related deaths decreased by 42%. Twenty nine percent of all diabetes-related admissions and 28% of all diabetes-related deaths occurred in large central metropolitan areas while 40.4% of all diabetes-related admissions and 39.1% of all diabetes related deaths occurred in the South census region. In terms of individual characteristics, the highest

number of admissions and deaths occurred among individuals who were female, who were older adults, who were White, and among the privately insured.

Table 2 contains the bivariate and multivariate analysis showing the odds of a diabetes-related hospital death (compared to not dying during a diabetes-related hospitalization). The logistic regression models accounted for year and census region population estimates, and the results show that the odds of a diabetes-related hospital death were significantly associated with most of the categories of the geographic- and individual-level variables (Table 2). Multivariable analysis showed that with the exception of large fringe metropolitan areas, the odds of diabetes-related hospital deaths increased across the urban-rural continuum, and residents of micropolitan and noncore areas had 16.1% ($OR = 1.16$, 95% C.I. = 1.14, 1.18) and 20.7% ($OR = 1.21$, 95% C.I. = 1.19, 1.24) higher odds of dying, compared to residents of large central metropolitan areas, respectively. Compared to residents of the North-east, residents in the three other census regions were significantly

Table 1
Characteristics of diabetes-related hospital deaths, 2009–2015^a National Inpatient Sample.

| Variable | Diabetes-related hospital admissions (n) | Diabetes-related hospital deaths (n) |
|----------------------------|--|--------------------------------------|
| Total | 9,515,894 | 147,069 |
| Year | | |
| 2009 | 1,424,528 | 24,566 |
| 2010 | 1,442,219 | 23,489 |
| 2011 | 1,529,234 | 23,685 |
| 2012 | 1,385,061 | 20,925 |
| 2013 | 1,362,753 | 20,748 |
| 2014 | 1,338,966 | 19,464 |
| 2015 ^a | 1,033,133 | 14,192 |
| Rural-urban classification | | |
| Large central metropolitan | 2,767,846 | 41,207 |
| Large fringe metropolitan | 2,127,911 | 30,697 |
| Medium metropolitan | 1,788,395 | 27,261 |
| Small metropolitan | 875,507 | 13,871 |
| Micropolitan | 1,071,215 | 18,415 |
| Noncore | 768,979 | 13,830 |
| Census region | | |
| Northeast | 1,778,339 | 27,432 |
| Midwest | 2,224,237 | 32,210 |
| South | 3,848,922 | 57,465 |
| West | 1,664,396 | 29,962 |
| Age | | |
| 0–17 | 73,066 | 515 |
| 18–29 | 240,466 | 675 |
| 30–44 | 781,351 | 3420 |
| 45–54 | 1,361,663 | 9677 |
| 55–64 | 2,066,319 | 21,445 |
| 64–74 | 2,293,170 | 34,014 |
| ≥ 75 | 2,698,332 | 77,293 |
| Race/ethnicity | | |
| White | 5,631,472 | 93,191 |
| Black | 1,588,853 | 19,791 |
| Hispanic | 1,001,451 | 13,506 |
| Asian/Pacific Islander | 209,079 | 4480 |
| Native American | 71,630 | 945 |
| Other | 256,182 | 4013 |
| Missing | 757,227 | 11,143 |
| Insurance coverage | | |
| Commercial/private | 5,654,860 | 105,984 |
| Medicare | 1,131,564 | 10,474 |
| Medicaid | 2,005,707 | 20,650 |
| Self-pay/uninsured | 404,846 | 4205 |
| Other | 299,194 | 5300 |
| Gender | | |
| Male | 4,565,083 | 74,531 |
| Female | 4,949,268 | 72,527 |
| Charlson Comorbidity Score | | |
| 0–2 | 5,941,874 | 68,429 |
| 3–4 | 2,671,310 | 51,595 |
| 5+ | 902,710 | 27,045 |

Note: Rural-urban, age, insurance coverage and gender classifications were missing for 116,041, 1527, 19,723 and 1543 inpatient discharge records respectively.

^a Only January to August 2015 NIS discharges are included.

Table 2
Unadjusted and adjusted odds of diabetes-related hospital deaths by rurality and hospital census region.

| Variable | Bivariate odds ratios (95% C.I.) | Multivariable odds ratios (95% C.I.) |
|----------------------------|----------------------------------|--------------------------------------|
| Urban-rural continuum | | |
| Large central metropolitan | Reference | Reference |
| Large fringe metropolitan | 0.97(0.96–0.99)*** | 0.96(0.95–0.98)*** |
| Medium metropolitan | 1.04(1.02–1.05)*** | 1.03(1.01–1.05)*** |
| Small metropolitan | 1.08(1.06–1.10)*** | 1.08(1.06–1.10)*** |
| Micropolitan | 1.17(1.15–1.19)*** | 1.16(1.14–1.18)*** |
| Noncore | 1.23(1.21–1.26)*** | 1.21(1.19–1.24)*** |
| Hospital census region | | |
| Northeast | Reference | Reference |
| Midwest | 1.17(1.10–1.25)*** | 1.18(1.10–1.26)*** |
| South | 3.16(2.25–4.43)*** | 3.37(2.39–4.75)*** |
| West | 1.65(1.49–1.82)*** | 1.73(1.56–1.91)*** |
| Gender | | |
| Female | Reference | Reference |
| Male | 1.12(1.11–1.13)*** | 1.13(1.12–1.14)*** |
| Age category | | |
| 0–17 | Reference | Reference |
| 18–29 | 0.40(0.35–0.45)*** | 0.37(0.33–0.42)*** |
| 30–44 | 0.62(0.56–0.68)*** | 0.56(0.51–0.62)*** |
| 45–54 | 1.01(0.92–1.10) | 0.88(0.81–0.96)** |
| 55–64 | 1.48(1.35–1.61)*** | 1.27(1.16–1.39)*** |
| 65–74 | 2.12(1.94–2.32)*** | 2.02(1.85–2.21)*** |
| ≥75 | 4.15(3.80–4.53)*** | 4.04(3.70–4.41)*** |
| Race/ethnicity | | |
| White | Reference | Reference |
| Black | 0.75(0.74–0.76)*** | 0.93(0.92–0.95)*** |
| Hispanic | 0.81(0.80–0.83)*** | 0.91(0.90–0.93)*** |
| Asian or Pacific Islander | 1.30(1.26–1.34)*** | 1.15(1.12–1.19)*** |
| Native American | 0.79(0.74–0.85)*** | 0.89(0.83–0.95)*** |
| Other | 0.94(0.91–0.97)*** | 1.05(1.01–1.08)** |
| Missing | 0.86(0.84–0.87)*** | 0.92(0.90–0.94)*** |
| Primary payer | | |
| Private/commercial | Reference | Reference |
| Medicare | 1.84(1.82–1.87)*** | 0.87(0.86–0.88)*** |
| Medicaid | 0.90(0.88–0.92)*** | 1.15(1.12–1.17)*** |
| Self-Pay | 1.01(0.98–1.05) | 1.45(1.40–1.50)*** |
| Other | 1.74(1.69–1.80)*** | 1.73(1.68–1.79)*** |
| Charlson Comorbidity Score | | |
| 0–2 | Reference | Reference |
| 3–4 | 1.69(1.67–1.71)*** | 1.46(1.45–1.48)*** |
| 5+ | 2.66(2.62–2.69)*** | 2.27(2.23–2.30)*** |
| Year | | |
| 2009 | Reference | Reference |
| 2010 | 0.94(0.93–0.96)*** | 0.95(0.93–0.97)*** |
| 2011 | 0.90(0.88–0.92)*** | 0.91(0.90–0.93)*** |
| 2012 | 0.88(0.86–0.89)*** | 0.90(0.88–0.93)*** |
| 2013 | 0.88(0.87–0.90)*** | 0.92(0.90–0.94)*** |
| 2014 | 0.84(0.83–0.86)*** | 0.90(0.87–0.92)*** |
| 2015 | 0.80(0.78–0.81)*** | 0.85(0.82–0.88)*** |

Note: Bivariate and multivariate analyses accounted for population estimates and year
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

more likely to experience a diabetes-related hospital death, with the South having the highest odds (OR = 3.37, 95% C.I. = 2.39, 4.75), followed by the West (OR = 1.73, 95% C.I. = 1.56, 1.91), and Midwest census regions (OR = 1.18, 95% C.I. = 1.10, 1.26).

With regards to race/ethnicity, patients identified as Asian or Pacific Islander (OR = 1.15, 95% C.I. = 1.12, 1.19), and those in the 'Other' category (OR = 1.05, 95% C.I. = 1.01, 1.08), were more likely to experience death during a diabetes-related hospitalization, compared to patients identified as whites. The odds of death also increased with age, especially from age 55 years and onwards, with those aged 65–74 (OR = 2.02, 95% C.I. = 1.85, 2.21), and those older than 75 (OR = 4.04, 95% C.I. = 3.70, 4.41) having the highest odds of death during hospitalization. Males (OR = 1.13, 95% C.I. = 1.12, 1.14), those covered by Medicaid (OR = 1.15, 95% C.I. = 1.12, 1.17), who pay out of pocket (OR = 1.45, 95% C.I. = 1.40, 1.50), as well as those with other insurance (OR = 1.73, 95% C.I. = 1.68, 1.79) had higher odds of a hospital death compared to females and the privately insured, respectively. The odds of death also increased with higher comorbidity scores.

Separate multivariate logistic regressions were conducted to estimate the odds of diabetes-related death within each census region, adjusting for year and population estimates (Table 3). The main predictor included the six categories of urban/rural residence, and the reference category was the large central metropolitan area. Within the Northeast, the odds of death were 8% higher among residents of small metropolitan areas (OR 1.08, 95% C.I. 1.01–1.14) compared to large central metro areas. In the Midwest and South census regions, the likelihood of death increased with higher levels of rurality. The odds of death were 23% higher in both the micropolitan (OR 1.23, 95% C.I. 1.18, 1.28) and noncore (OR 1.23, 95% C.I. 1.18, 1.28) areas of the Midwest, and they were 25% higher in the micropolitan areas (OR 1.25, 95% C.I. 1.21, 1.28) and 29% higher in the noncore areas (OR 1.29, 95% C.I. 1.25, 1.33) of the South. In the West, residents of large fringe metropolitan and noncore areas also had 5.5% (OR = 1.06, 95% C.I. = 1.03, 1.09), and 10% (OR = 1.10, 95% C.I. = 1.02, 1.17) higher odds of death respectively.

The results were mixed with regards to race/ethnicity in census-specific analyses. In the Northeast and Midwest regions, Blacks and Hispanics were significantly less likely to die from a diabetes-related

Table 3
Adjusted odds of hospital diabetes-related deaths across the urban-rural continuum and census regions, 2009–2015.

| | Northeast OR (95% C.I.) | Midwest OR (95% C.I.) | South OR (95% C.I.) | West OR (95% C.I.) |
|-----------------------------------|----------------------------|--------------------------|------------------------|-----------------------|
| Urban-rural continuum | | | | |
| Large central metropolitan | Reference | Reference | Reference | Reference |
| Large fringe metropolitan | 0.88(0.85–0.91)*** | 1.00(0.97–1.04) | 0.97(0.94–1.00)* | 1.00(0.97–1.04) |
| Medium metropolitan | 0.85(0.82–0.89)*** | 1.14(1.10–1.19)*** | 1.05(1.03–1.08)*** | 1.06(1.03–1.10)*** |
| Small metropolitan | 1.08(1.01–1.14)* | 1.10(1.06–1.15)*** | 1.16(1.12–1.19)*** | 0.93(0.89–0.98)** |
| Micropolitan | 1.00(0.95–1.05) | 1.23(1.18–1.28)*** | 1.25(1.21–1.28)*** | 1.00(0.95–1.05) |
| Noncore | 0.98(0.91–1.06) | 1.23(1.18–1.28)*** | 1.29(1.25–1.33)*** | 1.10(1.02–1.17)** |
| Gender | | | | |
| Male | 1.07(1.04–1.10)*** | 1.11(1.08–1.13)*** | 1.15(1.13–1.17)*** | 1.16(1.13–1.19)*** |
| Female | Reference | Reference | Reference | Reference |
| Age category | | | | |
| 0–17 | Reference | Reference | Reference | Reference |
| 18–29 | 0.50(0.36–0.71)*** | 0.33(0.26–0.41)*** | 0.37(0.31–0.44)*** | 0.37(0.29–0.47)*** |
| 30–44 | 0.65(0.49–0.87)** | 0.48(0.40–0.58)*** | 0.55(0.47–0.63)*** | 0.64(0.53–0.78)*** |
| 45–54 | 1.02(0.78–1.34) | 0.80(0.67–0.96)* | 0.83(0.73–0.96)** | 1.02(0.85–1.23) |
| 55–64 | 1.56(1.19–2.05)** | 1.12(0.94–1.35) | 1.22(1.06–1.40)** | 1.40(1.17–1.68)*** |
| 65–74 | 2.49(1.89–3.27)*** | 1.87(1.56–2.24)*** | 2.01(1.76–2.31)*** | 1.95(1.62–2.34)*** |
| ≥75 | 5.28(4.02–6.94)*** | 3.6(3.06–4.39)*** | 4.05(3.53–4.65)*** | 3.72(3.09–4.47)*** |
| Race/ethnicity | | | | |
| White | Reference | Reference | Reference | Reference |
| Black | 0.91(0.87–0.94)*** | 0.85(0.81–0.88)*** | 0.97(0.94–0.99)** | 0.93(0.89–0.98)** |
| Hispanic | 0.86(0.82–0.90)*** | 0.75(0.69–0.81)*** | 0.93(0.90–0.95)*** | 0.97(0.94–1.00)* |
| Asian or Pacific Islander | 1.04(0.95–1.13) | 0.91(0.80–1.03) | 0.99(0.91–1.09) | 1.25(1.21–1.31)*** |
| Native American | 0.71(0.52–0.98)* | 0.93(0.80–1.08) | 1.02(0.92–1.13) | 0.83(0.74–0.92)*** |
| Other | 0.98(0.93–1.05) | 0.94(0.87–1.02) | 1.07(1.01–1.14)* | 1.18(1.10–1.27)*** |
| Missing | 1.45(1.30–1.61)*** | 0.83(0.81–0.86)*** | 1.03(0.99–1.07) | 1.02(0.97–1.08) |
| Primary payer | | | | |
| Private/commercial | Reference | Reference | Reference | Reference |
| Medicare | 0.80(0.76–0.83)*** | 0.85(0.82–0.88)*** | 0.82(0.80–0.84)*** | 1.07(1.03–1.11)*** |
| Medicaid | 0.97(0.92–1.03) | 1.14(1.08–1.21)*** | 1.14(1.09–1.19)*** | 1.29(1.23–1.35)*** |
| Self-Pay | 1.22(1.11–1.35)*** | 1.54(1.42–1.66)*** | 1.47(1.40–1.54)*** | 1.49(1.37–1.61)*** |
| Other | 1.35(1.22–1.49)*** | 2.20(2.05–2.35)*** | 2.02(1.94–2.11)*** | 1.01(0.93–1.09) |
| Charlson Comorbidity Score | | | | |
| 0–2 | Reference | Reference | Reference | Reference |
| 3–4 | 1.55(1.51–1.59)*** | 1.36(1.33–1.40)*** | 1.47(1.45–1.50)*** | 1.48(1.44–1.52)*** |
| 5+ | 2.49(2.41–2.57)*** | 2.06(1.99–2.12)*** | 2.32(2.26–2.37)*** | 2.23(2.16–2.30)*** |
| Year | | | | |
| 2009 | Reference | Reference | Reference | Reference |
| 2010 | 0.93(0.89–0.97)*** | 0.93(0.90–0.97)*** | 0.96(0.94–0.99)* | 0.93(0.89–0.97)*** |
| 2011 | 0.90(0.86–0.93)*** | 0.90(0.87–0.94)*** | 0.89(0.87–0.92)*** | 0.85(0.82–0.89)*** |
| 2012 | 0.82(0.78–0.85)*** | 0.99(0.95–1.03) | 0.84(0.82–0.87)*** | 0.83(0.80–0.87)*** |
| 2013 | 0.81(0.77–0.85)*** | 1.01(0.97–1.05) | 0.84(0.81–0.86)*** | 0.85(0.81–0.88)*** |
| 2014 | 0.77(0.74–0.81)*** | 0.94(0.90–0.98)** | 0.80(0.78–0.83)*** | 0.85(0.81–0.88)*** |
| 2015 | 0.78(0.74–0.82)*** | 0.88(0.84–0.92)*** | 0.80(0.77–0.82)*** | 0.65(0.62–0.68)*** |

Note: Analyses accounted for population estimates.

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

hospitalization compared to Whites ($p < 0.01$). However, in the South, Native Americans (OR 1.02, 95% C.I. 0.92, 1.13) and those in the 'other' race category (OR = 1.07, 95% C.I. = 1.01, 1.14), were more likely to die from diabetes-related hospitalizations compared to whites. However, the results for the Native Americans did not reach statistical significance. In the West, Asian/Pacific Islanders (OR 1.25, 95% C.I. 1.21–1.31) were more likely to die from diabetes-related hospitalizations compared to whites. Medicaid patients were more likely to die from diabetes-related hospitalizations compared to privately insured patients across the Midwest, South and West census regions ($p < 0.001$), while self-pay patients had higher odds of death across all regions. In all census-specific analyses, the odds of a hospital death increased with higher Charlson comorbidity scores.

4. Discussion

In this study, we set out to explore place-based variations in diabetes-related hospital deaths. In addition to variations across the urban-rural continuum, we were interested in variations by census region. We note several major findings based on our analyses. First, our findings suggest that there are, in fact, considerable place-based differences in the occurrence of diabetes-related hospital deaths. Across the nation as a whole, we found that compared to residents of large central metropolitan areas, residents of micropolitan and noncore areas were significantly more likely to experience a diabetes-related death while obtaining inpatient services. This finding appears to be consistent with other work showing that rural residents living with diabetes are less likely to obtain preventive services that may assuage the need for hospital care.³² These preventive services include regular hemoglobin A1c blood checks, foot checks, eye examinations, nutrition counseling, and diabetes education.³² Our findings and that of previous work identifying gaps in preventive services indicate that additional resources and opportunities for primary and outpatient care need to be directed toward rural communities.

Second, our findings indicate that the need for further resources and opportunities for improved outpatient and preventive diabetes-related care are most profound in the U.S. South and Midwest. In these regions, residents of medium metropolitan, small metropolitan, micropolitan and noncore areas were all more likely to experience a hospital diabetes-related death relative to their large central metropolitan resident counterparts. Nevertheless, in both regions, non-metropolitan area (i.e., micropolitan and noncore) residents had the highest odds of a diabetes-related hospital death than other residents along the urban-rural continuum. Thus, the need for innovation in diabetes education, nutrition management, screening, and provision of care is most needed in rural areas of the South and Midwest.

Other individual-level factors also play a critical role in the odds of diabetes-related hospital deaths. Our findings suggest that individuals covered through Medicaid are more likely to experience a hospital diabetes-related death relative to those covered under private or commercial insurance. Additionally, individuals who were not covered under insurance at all were also much more likely to experience a diabetes-related hospital death. Moreover, while race and ethnicity was missing for many observations in our data, persons identifying as Asian or Pacific Islander had higher odds of a diabetes-related hospital death in the West, and patients identifying as Native American and residing in the South had higher odds of such a death relative to Whites, but this difference did not reach statistical significance. While these findings on the relationship between race and ethnicity and diabetes-related death are not as robust as they could be given missing data, they are largely in line with previous work finding that minorities bear a disproportionate burden of undiagnosed diabetes, prediabetes, and metabolic syndrome than non-minorities.^{4,33} This may lead to the

seeking of care at more advanced stages of the disease,³⁴ and ultimately, death that occurs while receiving treatment.³³

Moreover, across all census regions, the uninsured were consistently more likely to experience a diabetes-related hospital death. Researchers have previously noted the complexity of caring for uninsured patients given their limited access to healthcare services.³⁵ Similar complexity has been observed among uninsured patients who identify with a minority race or ethnicity and reside in low socioeconomic status areas.³⁵ As such, particular attention should be paid to diabetes care provided in safety net healthcare facilities for the uninsured and to challenges facing minority persons living with diabetes. Diabetes care that is strategically targeted toward these populations and inclusive of care coordination is warranted.

Our findings suggest that while diabetes-related hospital mortality has declined over the years, there is still room for improvement in accessibility of care, diabetes self-management, and care coordination for residents of noncore areas, particularly in the South and Midwest, and among the uninsured, and racial and ethnic minorities. Despite the fact that diabetes has been deemed an ambulatory care sensitive condition, there are still segments of the U.S. population that are at higher risk of living with diabetes and of dying in hospital from complications of the disease. Future research should continue to explore effective service, prevention, and intervention solutions that can be offered so as to achieve equitable disease management across census regions and across the urban-rural continuum.

We note a few limitations of our work. As was mentioned above, previous studies have found that compared to Whites, minorities tend to carry a disproportionate share of the diabetes burden in terms of prevalence, hospitalizations, and short-term readmissions. Furthermore, researchers have projected that in the upcoming decades, Blacks will continue to have the highest percent prevalence of diabetes, and that Black women and women of other races will have the highest relative increases in diabetes prevalence.³⁶ Nevertheless, because of substantial amounts of missing race and ethnicity data in our sample, it is possible that our findings do not fully capture the odds of diabetes-related hospital mortality for minorities.

Moreover, our study did not take lifestyle and socioeconomic factors, such as physical activity, diet, and educational attainment, into consideration in our analyses, as they were not included in the available data. Additionally, due to data limitations, our work did not provide insight on cultural preferences with respect to food, attitudes toward physicians, access to care, or a preference for dying at home. These factors can bear on patient compliance with treatment plans, the seeking of health care, and ultimately, diabetes-related mortality. Future research should explore how these and other factors play a role in diabetes mortality and whether place-based disparities persist after controlling for these factors.

4.1. Conclusions

This study provides actionable intelligence with which to inform state and federal policy makers in several capacities. Demonstrating the wide inequities facing residents of non-metropolitan areas of the U.S. and those across regions (e.g., those in the South), provides a critical narrative that warrants discussion in Congress. Funding for targeted interventions across the life course that are culturally competent keeping in mind racial and ethnic differences and cultural variation across regions is of critical importance. Namely, future research should continue to examine the most effective types of service delivery, interventions, and self-management education that can be rendered to disproportionately burdened communities in an effort to alleviate diabetes-related mortality. The current state with wide inequities must continue to be addressed in future research as well. In so doing, physicians, policymakers, public health professionals, and other stakeholders will be able to act on timely information thereby informing where and to whom targeted diabetes

interventions and education should be directed with the hope of ameliorating longstanding health inequities facing millions of vulnerable individuals residing in the U.S.

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