The Neighborhood Where You Live Is a Risk Factor for Stroke

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Background—The excess stroke mortality in the southeastern states of the United States (stroke-belt states) is well known; however, the factors associated with this pattern have not been fully elucidated. We measured the contribution of several demographic factors by analyzing stroke mortality data (2005–2009) at the census block group (BG) level in the state of Arkansas.

Methods and Results—Census BGs were used as proxies for neighborhoods. BGs were stratified using 5 census measures: poverty (percent of population below federal poverty level), population density (population per square mile), education (percent of population aged >25 years who did not graduate from high school), population mobility (percent of population who resided at the same address 1 year ago), and the percent of non-Hispanic blacks (percent of population that is black). Generalized additive models were used to estimate the variation in stroke mortality among BGs and to assess the impact of different demographic variables. From 2005 to 2009, there were 8930 stroke deaths in Arkansas. There was considerable variation in the relative risk even between adjacent BGs within a single county. The geographically weighted regression analyses indicated that 4.5% to 9% of deviance in stroke mortality among BGs could be explained by poverty, education, population density, and population mobility. Race/ethnicity (non-Hispanic blacks) explains <2% of the deviance in stroke mortality among BGs.

Conclusions—Our study shows that primordial risk factors such as poverty and education drive disparities in stroke mortality among neighborhoods in Arkansas.

Key Words: education • residence characteristics • stroke

The geographical variation in excess stroke mortality in the southeastern states of the United States (stroke-belt states) was described first nearly a half a century ago. The excess mortality in these states remains unexplained, although the original risk-factor hypothesis implicated differences in age, sex, prevalence of high blood pressure, diabetes mellitus, smoking, high cholesterol, history of heart disease, and the low use of antihypertensive medications. However, data from a national community-based cohort study, Reasons for Geographic and Racial Differences in Stroke (REGARDS), that used the Framingham Coronary Heart Disease and Stroke Risk Score to predict stroke mortality rates, found that these factors did not explain all excess mortality seen in these states. Even though more blacks reside in these states as compared with the rest of the country, excess mortality crosses racial lines in the stroke-belt states. Race accounts for ≈20% of the excess stroke mortality. Liao et al found that socioeconomic status (education and income) alone accounts for 32% of the excess mortality in the stroke-belt states. National Health and Nutrition Examination Survey (NHANES) III showed that per capita income is independently and inversely associated with risk of stroke, and ethnicity itself is not independently associated with stroke after adjusting for income, suggesting a strong ethnicity–income association. Socioeconomic status seems to be an independent risk factor for stroke similar to hypertension. Birth place, nativity, and place of residence as an adult have also been implicated in some studies as a basis for excess mortality, suggesting that environmental exposure, regional diet, and water and soil characteristics may contribute to the risk of excess stroke deaths.

Some investigators have implicated neighborhoods in the occurrence of stroke deaths, with those living in socioeconomically disadvantaged neighborhoods having a higher risk. Census tracts were used as proxies for neighborhoods in these studies. Only 1 study to date (the Cardiovascular Health Study) has assessed the differential impact of socioeconomic status, race, and neighborhood characteristics (at the census tract level) on the risk of stroke. Also, only 1 study examined the association between neighborhood cohesion and stroke mortality. The purpose of our study was to examine the risk of stroke at the smallest geographical unit possible, census.

Received March 29, 2013; accepted September 3, 2013.

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The online-only Data Supplement is available at http://circoutcomes.ahajournals.org/lookup/suppl/doi:10.1161/CIRCOUTCOMES.113.000265/-/DC1.

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Circ Cardiovasc Qual Outcomes is available at http://circoutcomes.ahajournals.org

DOI: 10.1161/CIRCOUTCOMES.113.000265
WHAT IS KNOWN

• Stroke is an important cause of death in the United States, especially in the southeastern states (the stroke belt).
• Although the role of traditional risk factors for stroke (eg, hypertension and smoking) are well known, the importance of social factors as risk factors are poorly understood.

WHAT THE STUDY ADDS

• This study explored the risk of stroke at the smallest geographical unit possible, census block group (neighborhood) in the state of Arkansas.
• At the neighborhood level, poverty, education level, population density, and population mobility accounted for 4.5% to 9% of the deviance in stroke mortality.
• Race and ethnicity were less important contributors to the deviance in stroke mortality (<2%).

Methods

Census BGs were used as proxies for neighborhoods. Arkansas has 2136 BGs as defined in the 2000 census. BGs are the smallest geographical areas for which the American Community Survey tabulates data. BG-level data for Arkansas were obtained from the summary files at the US Census Bureau web site (www.census.gov, American Community Survey, 2005–2009). We used a combined race/ethnicity variable that stratified the BG population as non-Hispanic whites, non-Hispanic blacks, Hispanics, and a race other than white or black, or the race/ethnicity was undetermined. The 2005 to 2009 American Community Survey estimated BG-level populations for several variables, and the following were selected for each BG: the number of people by age and sex, the number of people living in a household where income in the preceding year was below the federal poverty level, the number of people aged ≥25 years who did not complete high school, the number of people who were non-Hispanic blacks, and the number of people with the same residence as 1 year ago. These data were selected to rank BGs by racial/ethnicity, education, poverty, population density, and population mobility. We used the Principal Component Analysis method to obtain the first principal component (see the online-only Data Supplement for details on Principal Component Analysis), and this was used to combine neighborhoods (census BGs) with similar profiles based on these 5 covariates. 15,16 We assessed for multicollinearity among our 5 covariates by calculating the variance inflation factor. Our largest variance inflation factor among the 5 covariates was for poverty (variance inflation factor=1.59); hence, we concluded that multicollinearity does not affect our study results. Combining the census BGs helped us to get adequate numbers because several of the BGs by themselves have too few people in them to calculate meaningful inferences.

Geocoding Stroke Deaths

Death certificates from 2005 to 2009 for the state of Arkansas that coded stroke as an underlying cause of death with International Classification of Diseases, Tenth Revision codes I60 to I69 were obtained. Data on age, race/ethnicity, and sex were obtained directly from the death certificate. The residential address of each case was geocoded to a latitude/longitude along with a score that indicates the quality of the assignment. Ninety-three percent of the cases were geocoded to the latitude and longitude of the residence (exact place of residence). The rest of the cases (6.8%) were assigned to the latitude and longitude of the post office for the ZIP code. We examined the variation in relative risk (RR) estimates attributable to alternative BG assignment (see the online-only Data Supplement), and this source did not have a large effect on the estimates. A BG was assigned from the geocoded latitude/longitude using functions in MATLAB Mapping Toolbox (The Mathworks, Inc., Natick, MA) and TIGER shapefiles for the 2000 census BGs, which were downloaded from the Census Bureau. We also used MATLAB Mapping Toolbox to map the RR estimates for BGs in Arkansas and in Pulaski County, AR. The Science Advisory Committee of the Arkansas Department of Health, which serves as the Institutional Review Committee for the agency, approved the data use and the project. Only deidentified data were obtained for analysis and reporting; hence, the need for informed consent was waived by the Science Advisory Committee.

Statistical Analysis

A single BG has too few persons to directly estimate stroke mortality rates with reasonable precision. Synthetic estimates using generalized additive models (PROC GAM, SAS Institute, Cary, NC) were constructed to achieve adequate precision. 17 Age- and sex-specific stroke mortality rates in BGs were obtained from the Arkansas rate multiplied by a BG-specific RR. RRs were estimated by trends with changes in American Community Survey-derived BG measures. These RRs were further adjusted for spatial trends with geographically weighted Poisson regression using distances among BG centers. 18,19 The fit was reported using R² value (coefficient of determination). 20 The statistical methods are described in detail in the online-only Data Supplement.

Sensitivity Analysis

Of the 2134 BGs in Arkansas, non-Hispanic whites and non-Hispanic blacks combined constitute less than half of the population in only 29 (1.4%) BGs. These BGs were dropped from the analysis because the BG estimates were calculated using Arkansas age- and sex-specific rates, which are dominated by data from non-Hispanic whites and non-Hispanic blacks. We conducted 2 sensitivity analyses: one by including all 2134 BGs and estimating their rates using the state rates for non-Hispanic whites and non-Hispanic blacks and the other by dropping 241 (11.3%) BGs that have <85% of their population, non-Hispanic whites and non-Hispanic blacks combined.

Results

From 2005 to 2009, there were 8930 stroke deaths reported in the state of Arkansas. Of these deaths, 7391 (82.8%) were
non-Hispanic whites, 1352 (15.1%) were non-Hispanic blacks, and the remaining 187 (2.1%) were Hispanic or a race other than white or black, or the race/ethnicity was undetermined. Figure 1 shows the stroke mortality rates by age and sex for non-Hispanic whites and non-Hispanic blacks. Non-Hispanic blacks had substantially higher rates than non-Hispanic whites. Among Arkansans aged 35 to 64 years, males had higher rates than females. The sex and race/ethnicity differences in stroke mortality rates were most marked in the youngest age group (35–64 years) and least in the oldest age group (280 years). Many of the stroke deaths (38.2%) occurred among people aged >84 years. However, 15.6% of the deaths occurred at age <65 years where race/ethnicity and sex disparities were largest. Race/ethnicity differences in mortality mean that neighborhoods (BGs) with a large proportion of non-Hispanic blacks will be expected to experience higher stroke mortality rates. Also, combining the census BGs helped us to get adequate numbers because several of the BGs by themselves had too few people to make meaningful inferences. The percent of the BG population that was black was significantly correlated with BG measures of poverty, education, and urbanization ($P<0.0001$). The correlation with the percent living below the federal poverty level was 0.42. The correlation with population density was 0.33, and the correlation with the percent who did not graduate from high school was 0.18. The correlations among these BG covariates suggest that at least some of the race disparity is attributable to disparities associated with measures of poverty, education, and urbanization.

Neighborhood (BG) estimates of RR of stroke mortality are mapped in Figure 2 (RR: risk of a stroke death in the BG relative to the corresponding age- and sex-specific rate for Arkansas, 2005 to 2009. GAM indicates general additive model; GWR, geographically weighted regression; and NA, BGs that contained no residents in the age group or BGs where non-Hispanic black and non-Hispanic white populations make up less than half of the BGs residents.

![Figure 2](http://circoutcomes.ahajournals.org/)

**Figure 2.** A to D, Block group (BG)-specific estimates of the relative risk of stroke mortality in Arkansas, 2005 to 2009. GAM indicates general additive model; GWR, geographically weighted regression; and NA, BGs that contained no residents in the age group or BGs where non-Hispanic black and non-Hispanic white populations make up less than half of the BGs residents.
the state). RRs were computed within age groups because stroke mortality rates became more homogenous across BG with increasing age (Figure 2A, 2C, and 2D). Figure 2 shows the variability in stroke mortality rates across BGs. Among individuals aged 35 to 64 years, RR estimates in adjacent BGs differed by as much as 4-fold at times even within a single county (Figure 2B, Pulaski County). We chose to highlight Pulaski County because some of the highest and lowest estimated rates for Arkansas were found there; furthermore, it illustrated the large differences in RR even among adjacent BGs. We chose to show only the age range 35 to 64 years because the disparities are greatest at these age groups. There was considerable homogeneity in RRs among individuals aged 75 to 84 years. Overall, northwest Arkansas had the lowest rates, and the eastern and southeastern parts of Arkansas had the highest rates of stroke mortality. This northwest/southeast disparity correlated with the distribution of BGs with relatively low or high percentage of non-Hispanic blacks, respectively. To some extent, the risks associated with poverty and lower education are confounded with the risk associated with being black. We note that the majority of BGs in Arkansas have <25% of its population as non-Hispanic blacks. This suggests poverty crosses racial lines in the state.

Figure 3 shows the percent of the deviance (100x$R^2$) that is explained by the individual covariates and their first principal component. First principal component explains most of the deviance at all ages, followed by being black, poverty, education, population mobility, and population density. Figure 4 illustrates the incremental increase in deviance by sequentially adding BG covariates to the regression model beginning with poverty, then adding other variables. These covariates combined with spatial (geographically weighted regression) adjustments explain 9.6% to 14.4% of the deviance in stroke mortality across age groups. All BG variables were statistically significant in ≥1 age group. The overall explanatory value of these BG variables declines with age. Further analysis showed that 4.5% to 9% of the deviance in stroke mortality between BGs can be explained by poverty, education, population density, and population mobility. Race/ethnicity (non-Hispanic blacks) explains <2% of the residual deviance in stroke mortality between BGs, indicating the significance of poverty and education over race and its association with racial minorities. Together, the 5 BG covariates explain 10.6% of the deviance among BGs at age 35 to 64 years and 6.1% at age 65 to 74 years (Figure 4). These 2 age groups have the largest differences in the RR of stroke death among neighborhoods (Figure 2A and 2C).

The results from the sensitivity analyses did not change the overall conclusions in the explained deviance by the 5 variables. This is likely attributable to the fact that the race/ethnicity variable in Arkansas is predominantly driven by non-Hispanic blacks and non-Hispanic whites.

**Discussion**

Describing the stroke mortality at the neighborhood (BG) level helps to identify neighborhoods with excess mortality and the role of neighborhood attributes such as poverty, education, race/ethnicity, population density, and population mobility in excess mortality. To our knowledge, this is the first study to describe the stroke mortality at the smallest possible neighborhood units (census BGs) and to estimate the relative contribution of socioeconomic status, population density, population mobility, and race/ethnicity in stroke mortality.

Stroke mortality rates vary widely across the state of Arkansas. Understanding the variation at the neighborhood level would assist in public health program planning and implementation. The rate differences associated with neighborhood attributes have a strong age interaction, with the greatest neighborhood variation observed among those...
aged 35 to 64 years. We confirmed the well-known phenomenon of higher stroke mortality rates among non-Hispanic blacks in the population as a whole (Figure 1). We further expand on this observation by showing that the neighborhoods with higher stroke mortality rates have larger proportions of non-Hispanic blacks (eg, Figure 2A). The magnitude of disparity associated with BG covariates is impressive. For example, there was a 4-fold difference in stroke mortality rates between adjacent neighborhoods (BGs) even within a single county (Figure 2B, Pulaski County, AR). About 4.5% to 9% of deviance in stroke mortality among neighborhoods was explained by poverty, education, population density, and population mobility. Interestingly, after adjusting for these covariates, race/ethnicity (non-Hispanic blacks) explains <2% of the deviance. The impact of these variables to predict stroke mortality generally declined with age. These risk factors (particularly lower education and poverty) seem to be less relevant in older age groups because their access to health care improves as they become eligible for Social Security benefits and Medicare.

The impact of BG-level lower education and poverty in predicting stroke mortality can be explained in many ways. Lower education and poverty in a neighborhood limits access to healthy choices (fruits and vegetables, access and availability of venues for physical activity) and affects medication use (poor affordability and compliance for blood pressure medications) and access to healthcare providers and facilities. Impoverished neighborhoods tend to have more fast-food restaurants, and the neighborhoods with more fast-food restaurants have increased risk of stroke. Also, individuals with lower education and poverty tend to live in smaller homes in densely populated neighborhoods and are less likely to move out of the neighborhoods because of fewer job opportunities elsewhere. On the contrary, greater neighborhood-level social cohesion was found to be independently protective against stroke mortality. Among people aged 18 to 64 years, >25% do not have health insurance, and the percent is even higher among those in the low-income group. In contrast, people aged ≥65 years have Medicare health insurance and have better access to health care. This may explain part of the observation that neighborhood disparities in stroke mortality are less striking among people aged ≥65 years.

There are limitations to our study. Information on individual-level risk factors such as presence and management of hypertension, diabetes mellitus, smoking, and other comorbid conditions were not collected and are not included in the analysis. The proportion of the population in the neighborhoods (BGs), who spent appreciable time living elsewhere, is likely to increase with age, particularly with the older adults living with children and moving to retirement communities and nursing homes. Hence, people dying at 35 to 64 years of age are more likely to have received the relevant exposures (neighborhood risk factors such as fast-food restaurants and cohesion) while living in their neighborhood. About 2.5% of the cases were geocoded using 5-digit ZIP codes, which are prone to BG misclassification. Our results would be generalizable only to neighborhoods predominantly populated by non-Hispanic blacks or non-Hispanic whites and not to other race/ethnicity groups because their numbers were too small.

Our study illustrates the marked variability of stroke mortality among neighborhood units, the census BGs, and sets out the relative contribution of socioeconomic status and race/ethnicity in excess stroke mortality. Policymakers and public health planners should focus on primordial risk factors such as poverty and education that drive the disparities in stroke mortality among neighborhoods rather than a particular race alone. Focusing on improving neighborhoods (BGs) with high stroke mortality rates through community-based public health efforts could assist in decreasing these disparities. Identifying and targeting neighborhoods with high mortality rates and improving their socioeconomic conditions, improving access to health care, promoting healthy food alternatives, and fostering cohesion among neighbors are strategies that will decrease disparities in stroke mortality among neighborhoods.

Disclosures

None.

References

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Circ Cardiovasc Qual Outcomes. 2013;6:668-673; originally published online October 22, 2013;
doi: 10.1161/CIRCOUTCOMES.113.000265
Circulation: Cardiovascular Quality and Outcomes is published by the American Heart Association, 7272
Greenville Avenue, Dallas, TX 75231
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Print ISSN: 1941-7705. Online ISSN: 1941-7713

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://circoutcomes.ahajournals.org/content/6/6/668

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