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Exposure to the US Stroke Buckle as a Risk Factor for Cerebrovascular Mortality

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Key Words
Stroke Buckle, southeastern USA · Cerebrovascular disease · Geography

Abstract
Background: For decades, the Stroke Buckle region in the southeastern USA has had a high incidence of deaths from cerebrovascular disease relative to the rest of the country. We test here the possibility that temporary exposure to the Stroke Buckle can explain some of the excessive stroke mortality there. ***Methods:*** We examined all US death records between 1979 and 1988, noting whether individuals died inside or outside the 153-county Stroke Buckle in the coastal plains of North Carolina, South Carolina and Georgia. We also noted the decedents' county of residence, which was coded separately. Proportionate mortality ratios (PMRs) were used to assess the risk of dying of a stroke. ***Results:*** Stroke Buckle residents who died in their home county were at an increased risk of dying of a stroke (PMR = 130.2; 95% confidence interval, CI = 128.9–131.6; $p < 0.0001$). Visitors to the Buckle were also at an increased risk of dying of a stroke (PMR = 111.9; 95% CI = 107.5–116.2; $p < 0.0001$), and Buckle residents who died while outside of the region were less likely to die of a stroke (PMR = 89.9; 95% CI = 86.2–93.6; $p < 0.0001$). ***Conclusions:*** These results show that even short-term exposure to the Stroke Buckle accounts for some of the elevation in stroke deaths there.

Introduction

For over five decades, a 153-county region comprising the coastal plains of North Carolina, South Carolina and Georgia has had a stroke mortality rate considerably higher than the rest of the USA [1–3]. This area, known as the Stroke Buckle, exists within the larger Stroke Belt, which is an 8- to 12-state area in the southeast that exhibits a stroke mortality rate about 1.3–1.5 times greater than the rest of the country [4, 5]. However, the Stroke Buckle, which has more consistently had the highest stroke mortality in the country [6], will be the focus of this paper.

Even more remarkable than the high stroke mortality in the Stroke Belt and the higher mortality in the Stroke Buckle is the mystery about its causes. There are at least 10 hypotheses advanced to explain these elevated levels of stroke fatalities, but so far none of these explanations have proven successful in explaining the higher stroke deaths in the region [3, 6, 7]. Adapted from Howard [6], table 1 presents these hypotheses, ordered on a continuum from 'unlikely causes' to 'uninvestigated causes'. The hypotheses near the top of the list are considered unlikely because studies have largely failed to support them as explanations for the elevated stroke mortality in the Stroke Belt. The hypotheses near the bottom of the list, which are more difficult to test, remain potential causes.

Some of these hypotheses allow for the possibility that acute exposure to the region can account for some of the

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variance in stroke deaths. Chronic exposure to the region, which would be predicted by having spent years in the region, might be related to factors such as socioeconomic status or diet, and would be based on the gradual accumulation of damage. Acute exposure to the region, however, would not require years of living in the region but would depend on merely being there, or perhaps very recently having been there, at the time of the disease's onset. Such a distinction has been shown to be important, for example, in heart attack mortality in New York City, where chronic exposure – living in the city – and acute exposure – being in the city at the time of the cardiovascular event – both contribute to that region's high proportion of infarction deaths [8]. Specifically, individuals just visiting New York City were at an increased risk of dying of a heart attack, and New York City residents who temporarily left the city were less likely to die of a heart attack, both evidence of the effect of acute exposure to New York City. Thus, in this paper we consider acute exposure to mean that a person is visiting a region, rather than living there.

To our knowledge, however, there have been no tests of acute-exposure hypotheses with regard to the regional concentration of stroke deaths in the Stroke Belt. We test here the possibility that acute exposure to the Stroke Buckle by people merely visiting the region will be associated with a greater incidence of stroke fatalities. We can test this hypothesis because US death records provide both the county of death and the county of residence of decedents. Thus, we can assess the stroke mortality for individuals who die in the Stroke Buckle but do not reside there. In addition to examining visitors to the Stroke Buckle, we also test whether Stroke Buckle residents are less likely to die of strokes while outside the region. If these effects exist, it would suggest that acute exposure to the Stroke Buckle accounts for some of the elevation in stroke deaths there, and this may give us insight into which of the hypotheses can best explain the elevated stroke mortality in the Buckle.

Materials and Methods

We analyzed all US death records within the years 1979–1988, the most recent year for which county-level data were made available. This amounted to more than 20 million total deaths during that time period. Data were collected by the National Center for Health Statistics, and all data were downloaded from the Inter-university Consortium for Political and Social Research website [9]. These records had information on the decedents' cause of death, the county in which they died, and their county of residence. We determined whether people died inside the 153 counties of the Stroke Buckle, located in the eastern halves of the Carolinas and Georgia [1], and also whether they resided within this region.

Since we cannot determine how many visitors there were to and from the Stroke Buckle, we could not calculate a specific death rate for visitors. Instead, we computed the proportion of total deaths that were due to strokes both inside and outside the Stroke Buckle to determine whether stroke deaths were either overrepresented or underrepresented for visitors. To do this, we used the proportionate mortality ratio (PMR), which can be used when there is no way to determine the overall size of a specific population of interest (e.g. visitors to a region, members of a specific occupation). For example, if one wanted to investigate whether there was an increased risk of accidental deaths among construction workers in a given city, it would not be possible to compute a death rate for accidents without knowing exactly how many people worked in construction in the city over a period of time. However, it would be possible to collect the causes of death of a sample of the city's construction workers in order to determine whether accidental deaths were overrepresented or underrepresented among all causes of death, relative to the rest of the city's population [10, 11].

With regard to stroke deaths, the PMR is the ratio (multiplied by 100) of the observed proportion of stroke deaths to the expected proportion of such deaths [12]. For example, a PMR value of 120 would indicate there were 1.2 times as many stroke deaths as would be expected, whereas a PMR value of 80 would indicate that there were 0.8 times as many stroke deaths as expected.

Three separate PMRs were calculated [8]. For the first, we determined the PMR for Stroke Buckle residents who died inside their home county in the Buckle. This compared the observed number of stroke deaths for Buckle residents who died inside their home county to the expected number. The expected value was computed using the proportion of stroke deaths in the rest of the USA among individuals who died inside their county of residence. For example, if the proportion of all deaths that were due to stroke in the rest of the USA (among those who died inside their home county) were 7.6%, this percentage was used to derive the expected value based on the total number of all deaths among Buckle residents who died inside their home county.

The second analysis compared the observed number of stroke deaths for non-Buckle residents who died while visiting the Buckle, to the expected number of such deaths. The expected number was computed using the proportion of stroke deaths in the rest of the USA among individuals who died *outside* their county of residence. This comparison group controlled for any differences in stroke risk for people who are likely to be traveling when they died. For example, if the proportion of all deaths that were due to stroke in the rest of the USA (among those who died outside their home county) were 8%, this percentage was used to derive the expected value based on the total number of all deaths among non-Buckle residents who died while visiting the Buckle.

The third analysis compared the observed number of stroke deaths among Buckle residents dying outside of the Buckle to the expected number. The expected value was calculated from the proportion of stroke deaths of Buckle residents who died inside their county of residence, with an adjustment for an increase in stroke proportions for those who died outside their county of residence in the whole USA. For example, if the proportion of all deaths that were due to stroke among Buckle residents dying inside their home county were 8.3%, and all US decedents were 0.2% more likely to die of strokes when traveling outside their county of residence, then 8.1% was used to derive the expected value based on the total number of all deaths among Buckle residents who died while outside the Buckle.

We computed identical analyses for all stroke deaths (ICD-9 codes 430–438). All observed and expected values were simultaneously standardized for individuals' sex, age (in decades) and race (white, black and other) so that any results would not be attributable to regional differences in these variables [13]. To standardize the expected stroke deaths, we computed separately for each sex/age/race group the proportion of deaths that were due to stroke. To illustrate an example of the first type of analysis discussed above, 11.2% of black female septuagenarian deaths were the result of stroke in the rest of the USA (outside of the Stroke Buckle). There were a total of 17,595 black female septuagenarian deaths in the Stroke Buckle (of all causes, over the 10-year period), so we expected that 1,967.1 would be due to stroke. This expected value was then summed across all of the sex/age/race groups to derive the standardized expected number of stroke deaths that occurred in the Stroke Buckle.

Results

Residents of the Stroke Buckle who died in their home county were at a considerably increased risk of dying of a stroke (table 2). This is consistent with prior reports for this region. Not only was the rate elevated for residents of the Buckle dying there, but the effect was also present for those who were just visiting, with non-Buckle residents dying in the Buckle of strokes at a higher-than-expected rate. Additionally, Buckle residents who died outside the region were considerably less likely to die of a stroke. These last two results are novel findings and suggest that short-term exposures to and from the Stroke Buckle are related to sizeable increases and decreases in the proportion of deaths due to stroke.

Discussion

For residents of the Stroke Buckle, a greater proportion of deaths are from strokes than is the case for the rest of the country. The present results suggest that explanations for this effect must account for the sizable contribution to mortality of individuals who are visiting the region when they die of a stroke. This acute-exposure effect was supported by the findings that (a) non-Buckle residents who visited the Buckle were more likely to die of a stroke and (b) Buckle residents who temporarily left the region were less likely to die of a stroke. To our knowledge, few investigations have distinguished between residents and visitors when considering geographical disparities in a disease's mortality [8, 14]. However, residency status seems to be an important variable, since here nonresidents comprised a large proportion of the stroke deaths that took place in the Stroke Buckle.

In examining the 10 hypotheses in table 1, we believe that 3 of these hypotheses could play a role in the acute exposure effects we observed. First, it is possible that the quality of health care is poorer in the Buckle than it is outside this region. Some studies have shown that in the southeastern states, there are fewer physicians per capita and a smaller percentage of individuals who have health care coverage, relative to the rest of the USA [6, 15]. However, this explanation requires that any risk from poor

Table 1. Ten hypotheses about the causes of mortality in the Stroke Belt, ranging from 'unlikely' to 'uninvestigated' causes

Racial differences
Coding of death certificates
Socioeconomic status differences
Quality of health care
Stroke fatality, rather than stroke incidence, is elevated
Prevalence of stroke risk factors (e.g. hypertension, diabetes)
Environmental factors associated with geography (e.g. air temperature, exposure to local toxins)
Lifestyle choices (e.g. smoking, diet)
Genetic factors
Infection rates

Adapted from Howard [6].

Table 2. Observed and expected deaths due to stroke

	Residents of the Buckle	Visitors to the Buckle	Residents away from the Buckle
Number of stroke deaths			
Observed	36,072	2,570	2,244
Expected	27,698	2,298	2,496
Observed – expected	8,374	272	–129
Total (all deaths)	365,907	30,951	30,330
Percentage of strokes			
Observed	9.9	8.3	7.4
Expected	7.6	7.4	8.2
Stroke PMR	130.2*	111.9*	89.9*
95% confidence interval	128.9–131.6	107.5–116.2	86.2–93.6

* $p < 0.0001$: significantly different from 100; two-tailed test.

health care is manifest more in stroke mortality than in other causes of death, since the present results could not simply be due to the overall risk of death being higher in the Buckle but that, of those who die, a greater proportion suffered strokes.

Second, the Stroke Buckle could have some specific infectious agents that lead to especially high levels of stroke mortality. A number of different kinds of infections have been associated with stroke onset [16, 17], and retrospective studies have shown that in 1/4–1/3 of stroke victims, infections have been detected in the week or month prior to stroke onset [18, 19].

Finally, there might be some other environmental factor, such as ambient air temperature, the presence of certain toxins in the local water supply or quality of the local soil characteristics, that causes a greater incidence of stroke fatalities in the Buckle. Whereas the eastern halves of the Carolinas and Georgia (the Stroke Buckle) are coastal plains, the western halves of the states are primarily mountainous regions. Thus, the Stroke Buckle's geography is distinct from its surrounding areas, which suggests that geographical variables may play a role in the higher stroke rate. Numerous environmental variables have been proposed to explain the increased stroke mortality in the region [7]. By and large, however, there have been few consistent relationships found between stroke onset and environmental variables [6, 7], outside of infectious agents.

One important limitation of this study is that the data could not tell us how long visitors may have stayed in a different county before they died, or for what reasons they were visiting. Additionally, without more detailed information about the decedents, we could not know whether certain types of individuals were more or less likely to visit particular regions. For example, we cannot rule out the possibility that non-Buckle residents who died while visiting the Buckle were more likely to hold certain risk factors associated with stroke mortality, such as being genetically related to a Buckle resident or having once lived in the Buckle. Moreover, we could not determine whether Buckle residents who died while outside the region were less likely to have certain risk factors for stroke mortality. Future investigations could examine individuals who are known to have suffered strokes while visiting the Stroke Buckle or having temporarily left the region, and gather information about the duration of these visits and any previous connection these individuals may have had to different regions.

Conclusion

The elevated stroke mortality in the Stroke Belt and the Stroke Buckle has led to hundreds of thousands of excessive deaths, billions of dollars in health care costs and immeasurable suffering for stroke victims and their families [20]. Our goal here was to show that even short-term exposure to the Stroke Buckle plays a role in this continuing epidemic, and we hope that our findings will encourage closer examinations of acute-exposure hypotheses in the future. An important next step will be to specify the underlying processes of these effects, with the hope that effective interventions will soon follow.

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References

1 Howard G, Anderson R, Johnson NJ, Sorlie P, Russell G, Howard VJ: Evaluation of social status as a contributing factor to the Stroke Belt region of the United States. Stroke 1997; 28:936–940.

2 Borhani NO: Changes and geographic distribution of mortality from cerebrovascular disease. Am J Public Health 1965;55:673–681.

3 Lanska DJ, Kuller LH: The geography of stroke mortality in the United States and the concept of a Stroke Belt. Stroke 1995;26: 1145–1149.

4 Lanska DJ: Geographic distribution of stroke mortality in the United States: 1939–1941 to 1979–1981. Neurology 1993;43:1839–1851.

5 Wing S, Casper M, Davis WB, Pellom A, Riggan W, Tyroler HA: Stroke mortality maps: United States whites aged 35–74 years, 1962–1968. Stroke 1988;19:1507–1513.

6 Howard G: Why do we have a Stroke Belt in the Southeastern United States? A review of unlikely and uninvestigated potential causes. Am J Med Sci 1999;317:160–167.

7 Perry HM, Roccella EJ: Conference report on stroke mortality in the southeastern United States. Hypertension 1998;31:1206–1215.

8 Christenfeld N, Glynn LM, Phillips DP, Shrira I: Exposure to NYC as a risk factor for heart attack mortality. Psychosom Med 1999;61:740–743.

9 National Center for Health Statistics: Multiple causes of death, 1984–1998 (Interuniversity Consortium for Political and Social Research web site). http://www.icpsr.umich.edu (accessed October 10, 2006).

10 Sun J, Shibata E, Hisanaga N, et al: A cohort mortality study of construction workers. Am J Ind Med 1997;32:35–41.
11 Dong W, Vaughan P, Sullivan K, et al: Mortality study of construction workers in the UK. Int J Epidemiol 1995;24:750–757.
12 Mausner JS, Kramer S: Epidemiology: An Introductory Text. Philadelphia, Saunders, 1985.
13 Bland M: An Introduction to Medical Statistics. New York, Oxford University Press, 2000.
14 Lanska DJ, Peterson PM: Effects of interstate migration on geographic distribution of stroke mortality in the United States. Stroke 1995;26:554–561.
15 Richardson A, Liao Y, Tucker P: Regional and racial differences in prevalence of stroke – 23 states and District of Columbia, 2003. MMWR Morb Mortal Wkly Rep 2005;54: 481–484.
16 Emsley HCA, Tyrrell PJ: Inflammation and infection in clinical stroke. J Cereb Blood Flow Metab 2002;22:1399–1419.
17 Ngeh J, Goodbourn C: *Chlamydia pneumoniae, Mycoplasma pneumoniae,* and *Legionella pneumophila* in elderly patients with stroke (C-PEPS, M-PEPS, L-PEPS): a case-control study on the infectious burden of atypical respiratory pathogens in elderly patients with acute cerebrovascular disease. Stroke 2005;36:259–265.
18 Ameriso SF, Wong VL, Quismorio FP, Fisher M: Immunohematologic characteristics of infection-associated cerebral infarction. Stroke 1991;22:1004–1009.
19 Macko RF, Ameriso SF, Barndt R, Clough W, Weiner JM, Fisher M: Precipitants of brain infarction: roles of preceding infection/inflammation and recent psychological stress. Stroke 1996;27:1999–2004.
20 Howard VJ, Acker J, Gomes CR, et al: An approach to coordinate efforts to reduce the public health burden of stroke: the Delta States Stroke Consortium. Prev Chronic Dis 2004;1:A19.