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Decline in US Stroke Mortality: An Analysis of Temporal Patterns by Sex, Race, and Geographic Region Editorial Comment: An Analysis of Temporal Patterns by Sex, Race, and Geographic Region

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Decline in US Stroke Mortality
An Analysis of Temporal Patterns by Sex, Race, and Geographic Region

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Background and Purpose—Although stroke mortality rates have declined rapidly over the past 30 years, the decline has slowed to a plateau. Here, we assess whether the race-sex-region groups have participated equally in this decline and whether there are groups in which stroke mortality rates are still declining, and we predict how these rates will eventually differ.

Methods—Data on stroke mortality in the United States between 1968 and 1996 were analyzed in a 3-step procedure: (1) we calculated "crude" age-adjusted stroke mortality rates by race, sex, and county; (2) we "smoothed" the rates across counties and years; and (3) we fit a model to describe the temporal pattern. From this model we calculated the percent decline in stroke mortality, the anticipated additional decline (thereby identifying regions that will continue to decline), and the anticipated eventual stroke mortality rates.

Results—Maps by race-sex-region group describe the above parameters. White men have experienced the largest decline in stroke mortality, and black men have seen the smallest. Generally, stroke mortality appears to still be slowly declining for blacks but not for whites. Geographic differences in stroke mortality are predicted to persist.

Conclusions—The analysis suggests that the Deep South (Alabama and Mississippi) will fall from the stroke belt and be replaced by other regions (notably Oregon, Washington, and Arkansas). New York City and southern Florida had low stroke mortality rates in 1968, have experienced large declines, and continue to experience declines, resulting in even larger relative heterogeneity of stroke mortality rates. The reasons for these differences in the pattern of the decline in stroke mortality are not understood. (***Stroke***. 2001;32:2213-2220.)

Key Words: cerebrovascular disorders ■ epidemiology ■ geography ■ mortality ■ racial differences

S troke mortality rates differ substantially by sex and race, with men having a mortality ratio ≈25% higher than women and blacks having a ratio 40% higher than whites.[1] There are also substantial geographic variations in stroke mortality rates, with residents of the "stroke belt" (North Carolina, South Carolina, Georgia, Alabama, Mississippi, Arkansas, Tennessee, and Louisiana) having a mortality ratio ≈40% higher than the rest of the nation.[2–4] Even within single states (both in the stroke belt and for the rest of the nation), stroke mortality rates can be quite heterogeneous.[5–7] For example, a "buckle" of the stroke belt has been identified in the coastal plain of North Carolina, South Carolina, and Georgia, where for select ages the stroke mortality rate is ≈100% higher than for the remainder of the nation.[8]

These differences in stroke mortality rates are made to be a dynamic process by the substantial temporal decline in the stroke mortality rate over the past 30 years.[1] Although stroke mortality rates were declining before the early 1970s, the rate of this decline increased at that time (approximately 1972).

See Editorial Comment, page 2218

During the early 1990s, the rate of decline in stroke mortality rates began to slow, and now stroke mortality rates are apparently no longer declining.[9–12] Over this 29-year period (1968 to 1996), there has been a remarkable 60% decline in stroke mortality.[1] It has been noted that the geographic regions with the highest stroke mortality have tended to shift across time.[13] However, noting that the location with the highest rates of stroke mortality are "migrating" with time fails to reflect the substantial temporal decline in stroke mortality rates. That is, the reason for migration of these regions with the highest stroke mortality may be attributed largely to the degree the different geographic variations participated in the decline in stroke mortality. As such, a region that appears to be increasing in stroke mortality relative to other regions may only be not declining as rapidly relative to other regions.

These observations led to several shortcomings in the current description of the decline in stroke mortality. First,

nationwide, the stroke mortality rate is no longer declining but rather has stabilized or reached a plateau. The geographic variations in the magnitude of decline in stroke mortality since the late 1960s have not been well described (ie, relative "participation" in the decline in stroke risk). Likewise, the extent to which the decline in stroke mortality has been shared by race (black and white) and sex strata has not been described by geographic region. Second, although the overall national stroke mortality rates may have reached a plateau, it is possible that there are regions in the United States where stroke mortality rates are continuing to decline or are still declining for specific race-sex strata. Finally, under the assumption that stroke mortality rates are still declining for some strata defined by sex, race, and geographic region, there has been no description of the magnitude of anticipated future decline.

The goals of this report are to address these shortcomings by (1) assessing the degree to which groups defined by sex, race, and geographic regions have shared the decline of stroke mortality in the past; (2) identifying race-sex-county strata with stable stroke mortality rates and those with rates that are continuing to decline; and (3) under the assumption that stroke mortality is reaching a plateau for all groups, predicting the final level of stroke mortality for each group.

Methods

These analyses use data from the Compressed Mortality File, provided by the National Center for Health Statistics. The Compressed Mortality File contains data on the number of deaths by county, age stratum, race, sex, year, and cause of death, as well as estimated population by county, age, race, and sex. These death and population estimates can be used to estimate age-specific mortality rates by cause of death. For the purpose of these analyses, stroke deaths were considered if the death certificate indicated an International Classification of Disease code reflecting any stroke subtype (ie, 430 to 438).

Because of the substantial differences in stroke mortality rates within states,[5–7] analyses were performed at the county level. The analysis to meet the above goals followed a 3-step procedure.

First, age-adjusted stroke mortality rates (with associated SE) were estimated at the county level. For each county, age-specific mortality was calculated within the age groups of 45 to 54, 55 to 64, 65 to 74, 74 to 84, and ≥85 years. The SE of each of these estimates was calculated with the normal approximation to the binomial distribution: $\sqrt{[p(1-p)]/n}$. Conservative assumptions were made to provide a nonzero estimate of the SE in the rare counties with no stroke deaths in an age stratum (as well as in counties in which all individuals in an age stratum died of stroke). In such counties, if there were ≥2 individuals in the age stratum, the SE (but not the rate) was calculated with the assumption that there was exactly 1 death. In the even rarer counties with only 1 individual in an age stratum, 0.5 was used as an estimate of the SE of the rate for that stratum. This number was chosen as the theoretical maximum value of the SE, provided as if one half of a person had died (ie, $\sqrt{(0.5(1-0.5))/1} = \sqrt{0.25} = 0.5)$.

The age-adjusted rate was then calculated as a weighted average (ie, a linear contrast) of the age-specific rates, with weights chosen to reflect the proportion of the 1990 US population in each stratum. The SE of the age-adjusted rate was calculated as the linear contrast of individual SE terms under the assumption that each was normally distributed.

Because of the relatively small population size of counties, the county-level estimates of stroke mortality rates from the first step of analysis are inherently unstable (ie, relatively large SE for many counties). This instability results in inconsistent patterns of stroke mortality rates that are likely caused by chance alone and
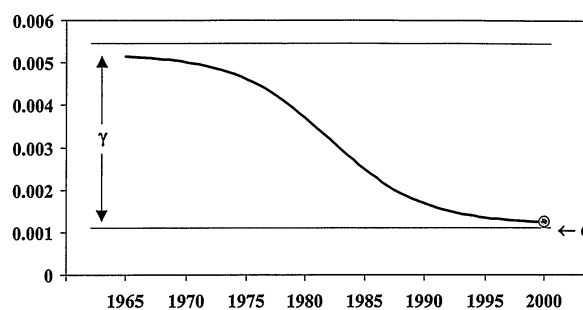

Figure 1. Four-parameter logistic function.

as such are difficult to interpret. Thus, in the second step of the analysis, these estimates were smoothed across year and geographical location with a kernel-like estimator.[14] This smoothed estimate is based on the assumption that the differences between the counties and across time change smoothly, and as such the large variations between contiguous counties that is caused by sampling error should be removed. The smoothed estimate of the stroke mortality rate is calculated as a weighted average of the observed stroke rate in all counties within a distance of ≈500 miles. The weights were chosen to reflect distances between counties, differences in calendar year of observation, and the precision of the estimates for each county.[15]

The third step of the analysis was to summarize the temporal pattern across the years from a 4-parameter logistic function:

$$SDR(t \backslash \alpha, \gamma, \beta_0, \beta_1) = \alpha + \gamma \left(\frac{1}{1 + e^{\beta_0 + \beta_1 t}} \right).$$

The 4-parameter logistic function was chosen both because it describes the temporal pattern of change in stroke mortality rates (the decline in the mortality rate increased during the early 1970s and then slowed to an asymptote in the 1990s) and because the parameters of the model (or functions of them) have clinical interpretation. The stroke death rate (SDR) was modeled as a function of calendar year (t) and 4 parameters (α, γ, β_0, and β_1). As can be seen in Figure 1, α is the asymptote or "floor" to which stroke mortality is approaching, and γ represents the theoretical difference between the floor stroke rate and the higher stroke rate at some time in the past. Like logistic regression, β_0 affects the year that the inflection of the s-shaped curve begins to decline more rapidly, while β_1 affects the steepness of the slope of the decline. This model was selected because it permits estimation of an asymptote if one exists. However, should the data for a race-sex group or for a region not reach an asymptote, ie, still show rapid declines, the "middle portion" of the logistic function can approximate a linear decline; thus, the model will indicate that the data for this cohort are not "plateauing."

Given the fitted line for each county, 3 parameters are of particular interest. These parameters correspond to the goals of the analysis described above. First, the percent decline in the stroke mortality rate over the 29 years was calculated from the fitted function values in 1968 and 1996 as $\{[(R_{68}-R_{96})/R_{68}] \times 100\}$, where R_k is the estimated rate from the logistic function in year k. Second, the percent that the function is above the asymptote, representing an index of whether the race-sex stratum in the specific county has reached the asymptote or is still declining, was calculated as $\{[(R_{96}-\alpha)/R_{96}] \times 100\}$. Finally, the estimated floor (α) provides the estimate of the eventual level of stroke mortality for the county under the assumption that the stroke mortality rates will asymptote as described by the logistic function.

Results

There were substantial differences in the pattern of decline in stroke mortality rates among strata defined by race, sex, and geographic region (see Figure 2a through 2d). For each race-sex stratum, the top row for each set shows smoothed stroke mortality rates that are displayed for 1968, 1982, and
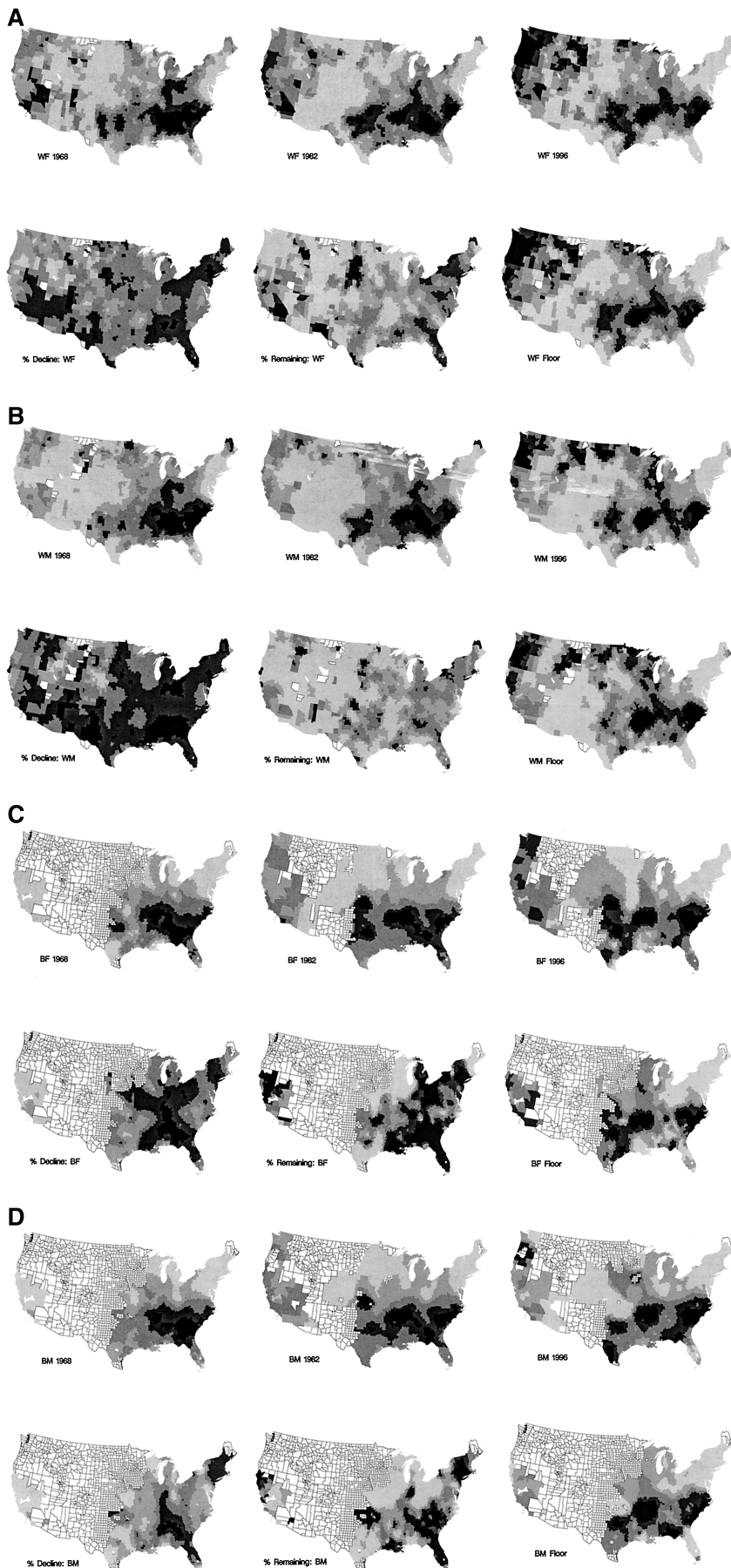
Figure 2. Top and bottom right, Stroke mortality rates by percentile. Top, Rates for specific years (1968, 1986, and 1996); bottom, anticipated lower floor for stroke rates. Shading for percentiles are from light to dark: 0 to 25th, 26th to 50th, 51st to 75th, 76th to 90th, and 91st to 100th. Bottom left, Observed percentage decline between 1968 and 1996, with shading for <50%, 50% to 55%, 51% to 60%, 61% to 65%, and >65%. Bottom center, Anticipated remaining percentage decline to the floor, with shading for <1%, 1% to 2%, 2% to 4%, 4% to 7%, and >7%. Unshaded areas in all maps have insufficient data for statistical analysis. a, White women; b, white men; c, black women; d, black men.
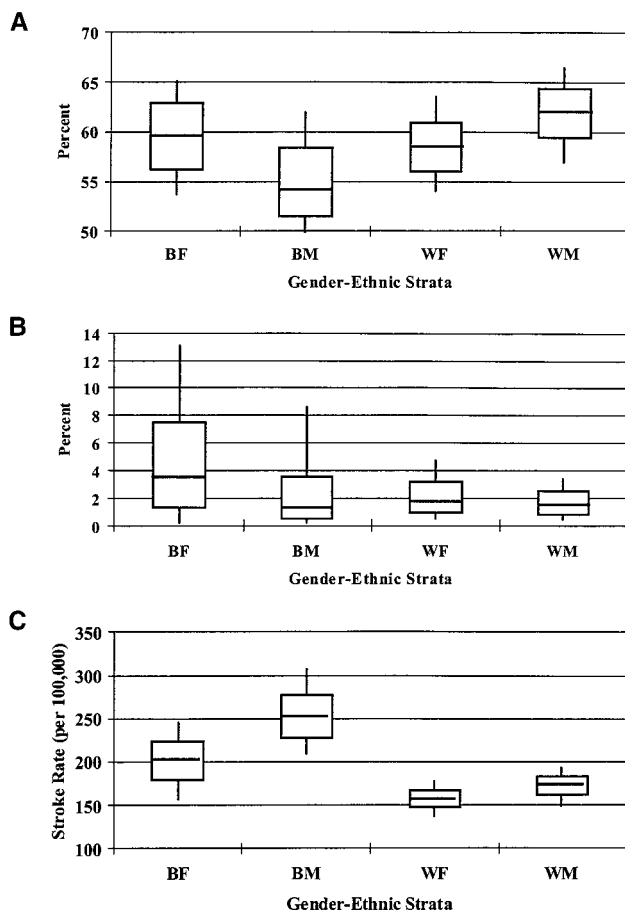
Figure 3. a, Box-and-whisker plots for the observed percent decline between 1968 and 1996 shown for 10th, 25th, 50th, 75th, and 90th percentiles across the counties. b, Box-and-whisker plots for the anticipated percent decline to the floor shown for 10th, 25th, 50th, 75th, and 90th percentiles across the counties. c, Anticipated floor (asymptote) for stroke mortality shown for 10th, 25th, 50th, 75th, and 90th percentiles across the counties. Note that the graphs were created with the use of almost all US counties for the white population but for a smaller number of counties (those displayed in Figure 2) for blacks.

1996. The bottom row provides the percent decline between 1968 and 1996 on the left, the anticipated decline to the floor (or asymptote) in the center, and the anticipated floor on the right.

Figure 3a through 3c shows box-and-whisker plots of the distribution across the counties of the percent decline between 1968 and 1996 (Figure 3a), the anticipated decline to the floor (Figure 3b), and the anticipated floor (Figure 3c). Some caution should be taken in contrasting the race-sex strata, because the distribution of these parameters is based on a different basis of counties; eg, counties in the Rocky Mountain region are included in the white but not black distribution of parameters. White men have experienced the largest decline in stroke mortality and black men the smallest decline, with women (regardless of race) showing intermediate declines (Figure 3a). For whites (regardless of sex), most counties have reached the asymptote for stroke rates, and there are few counties in which declines of >4% are anticipated (Figure 3b). This is in some contrast to blacks for

whom larger declines are anticipated. For black women, a further decline of ≈4% is anticipated in 50% of the counties, a further decline of ≈8% is anticipated in 25% of the counties, and a further decline of >13% is expected for 10% of the counties. Where the median anticipated further decline in stroke mortality rate for black men is similar to that for whites, the upper tail of the anticipated decline is substantially larger. For example, a decline of >8% is anticipated in 10% of the counties for black men. Unfortunately, the anticipated larger decline for blacks is not sufficient to remove the substantial racial difference in stroke mortality. As can be seen in Figure 3c, there is little overlap in the distribution of the anticipated stroke mortality rates across the race-sex strata.

Discussion

The pattern of decline in stroke mortality rates is a heterogeneous process, with substantial variations among population groups, geographic area, race, and sex. For most readers, the most interesting region is the area in which the reader is currently living; however, several interesting geographic patterns have regional and/or national importance.

First, regardless of race and sex, there have been substantial declines in stroke mortality rates in the Deep South (Alabama and Mississippi). For white men, these decreases between 1968 and 1996 have been >65%, whereas for white women, the decrease has generally been >60%. Similar large declines can be noted for blacks. Interestingly, stroke mortality rates in Alabama and Mississippi are still declining at a moderate rate, with declines of 2% to 7% anticipated. The substantial declines in the past and the anticipated moderate decline in the future suggest that these regions may fall from among those with the highest stroke mortality in the nation.

Although Alabama and Mississippi apparently are falling from the regions with the highest stroke mortality, they are being replaced by new "satellites" of the stroke belt. For Washington, Oregon, and Arkansas, the declines in stroke mortality have been relatively small. For white women, the decline in stroke mortality between 1968 and 1996 along the Pacific Coast of Washington and Oregon has generally been <55%, whereas the decline for white men has been <60%. The rate of decline for much of Arkansas has also been relatively slow, generally <60% for white men and women. For all 3 of these regions, stroke mortality rates have apparently reached a plateau, and little additional decline is anticipated in the future (<1%). Because these satellite regions have fallen relatively slowly and have apparently reached their plateau, the present analyses suggest that these are regions that will have increasing stroke mortality rates relative to other regions. Although there was an insufficient population of blacks to examine these changes in Washington and Oregon, the same pattern of only moderate decline and little anticipated future decline was observed for black men and women in Arkansas.

The coastal plain of North Carolina, South Carolina, and Georgia has been previously identified as the buckle of the stroke belt. In these analyses, this region experienced at most only a moderate decline in stroke mortality. For example, for white women, the decline in stroke mortality was <60%
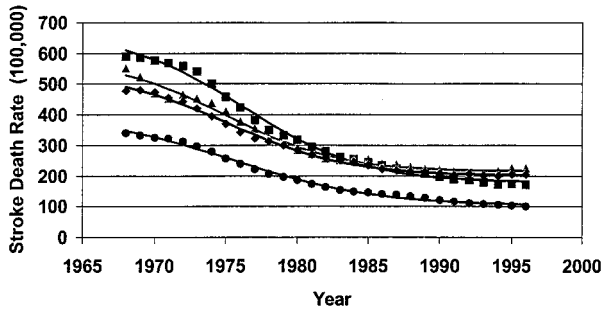
Figure 4. Smoothed stroke mortality rates for 4 counties: Jefferson County, Alabama (Birmingham; ■); Queens County, New York (New York City; ●); Multnomah County, Oregon (Portland; ◆); and Charleston County, South Carolina (Charleston; ▲).

(compared with Mississippi and Alabama, where the decrease was sometimes >65%). A similar relatively small decline was observed for blacks regardless of sex. There are also only moderately small anticipated future declines in stroke mortality in these regions. As such, it appears that these regions will persist as having relatively high stroke mortality rates.

Perhaps the most interesting regions in the nation are New York City and southern Florida. Both of these regions began with some of the lowest stroke mortality rates in the nation, particularly for whites. These regions have also experienced some of the largest declines in stroke mortality between 1968 and 1996, with declines >65% in many counties. These same regions are currently experiencing the fastest rate of decline in stroke mortality rates. For example, for white women, the stroke mortality rate is anticipated to decline an additional 7% before it reaches its asymptote. The facts that the stroke mortality rates began at a low rate, declined at the fastest rate in the nation, and continue to decline in these regions suggest that the relative degree of geographic heterogeneity will increase in the future.

In Figure 4, these changing relative stroke rates and the increase in heterogeneity are shown for 4 selected counties. In 1968, Jefferson County, Alabama (Birmingham), had among the highest stroke mortality in the nation, even higher than Charleston County, South Carolina (Charleston). However, the rate of decline has been faster in Jefferson County, and over time, stroke mortality has fallen below that observed in Charleston County. It is also apparent from these data that the decline in stroke mortality in Charleston County has reached an asymptote, whereas there is still a slight continuing decline in Jefferson County. The stroke mortality rates for Multnomah County, Oregon (Portland), began at a lower rate than observed for either Charleston or Jefferson County. However, the rate of decline has been relatively slow, and the stroke mortality rate in Multnomah is now nearly identical to that observed in Charleston County (and higher than that in Jefferson County). The rates for Multnomah County have also apparently reached their asymptote, because there has been little change since the early 1990s. The substantial differences in stroke mortality are apparent by contrasting the rates in Queens County (New York City) with other regions. In 1968, the rates were approximately one third lower in Queens County than in Charleston or Jefferson County. The decline in mortality has been substantial for Queens County,

and in 1996, the rates had decreased to approximately one half the rate observed in Charleston County. Hence, in a relative scale, the heterogeneity of stroke mortality rates increased over this period. Again, whereas Charleston and Multnomah counties have apparently reached a plateau, the rates for Queens County show a continued decline.

In analyses with county as the unit of analysis, white men experienced the largest percentage decline in stroke mortality rates between 1968 and 1996 (Figure 3a). The rate of decline was somewhat lower for women (regardless of race), with black men having the slowest rate of decline. The pattern of the anticipated future decline in stroke mortality (Figure 3b) suggests that there are few counties with continuing declines in stroke mortality for whites regardless of sex. However, there are still many counties with continuing declines in stroke mortality for blacks. Specifically, for black women, a further decline in stroke mortality of ≈4% or more is anticipated in 50% of the counties, and a decline of ≈8% is anticipated in 25% of the counties. Although the median value for the anticipated decline is similar for black men and white men (and women), there are several counties in which additional declines could be anticipated for black men. Specifically, future declines of ≈8% can be anticipated in ≈10% of the counties. Unfortunately, these anticipated larger future declines for blacks in stroke rates are not sufficient to remove the race and sex differences in stroke mortality rates (Figure 3c). As can be seen, the 10th percentile for stroke mortality rates for black men is anticipated to be above the 90th percentile for white men and white women. Across all counties, we would anticipate that the median stroke mortality rate for black men would be ≈250 per 100 000 compared with 200 per 100 000 for black women, 170 per 100 000 for white men, and 155 per 100 000 for white women.

These data and analyses have several shortcomings. First, the data rely on the appropriate stroke diagnosis on death certificates. Although there are numerous problems in the coding of death certificates, one could argue that the reliability for stroke diagnosis is acceptable for these analyses.[16] In a related concern, because of concerns that stroke subtyping is even more problematic, we chose to report trends for all-cause stroke mortality. It is possible that the trends for major stroke subtypes, such as infarction versus hemorrhage, do not reflect the changes observed in the overall rate. We are also making 2 major assumptions in the analyses of the data. The first assumption is that stroke mortality rates change relatively slowly between adjacent counties and across years, and thus it is reasonable to smooth these data. Although it is possible that stroke mortality changes abruptly between some contiguous counties, we think that most abrupt observed changes in the crude rates reflect sampling variation. However, this approach would mask the true abrupt changes between contiguous counties. In addition, we have chosen the 4-parameter logistic model to describe the temporal changes in stroke mortality. Although this model does describe the general overall pattern of stroke mortality rates (slow decline before 1970, faster decline between 1970 and 1990, slowing decline since 1990), it does not allow for the possibility that stroke mortality rates may increase in some counties. We have examined the residual values from the regression mod-

els, and the possibility that rates are actually increasing in recent years does not appear to be a major concern. However, a more careful examination of this possibility will be described in a subsequent publication; it is considered beyond the scope of this work.

In conclusion, there are substantial geographic, racial, and sex differences in the pattern of the decline of stroke mortality. These differences underlie a likely larger relative degree of heterogeneity of stroke mortality rates in the future. Although there are regions in which stroke mortality has reached a plateau, there are other regions in which further decline is likely. These changes should serve to support the further migration of the stroke belt. Specifically, the Deep South (Alabama and Mississippi) may fall from those regions with the highest stroke mortality, to be replaced with regions on the west coast (Oregon and Washington) and other regions in the south (Arkansas and western Tennessee). In addition, there are race and sex differences between the past and anticipated future declines. Although stroke mortality rates in most counties have reached an asymptote for whites, substantial declines continue for blacks, particularly black women, in many counties.

Acknowledgment

References

1. American Heart Association. *1999 Heart and Stroke Statistical Update*. Dallas, Tex: American Heart Association; 1999.
2. Lanska DJ. Geographic distribution of stroke mortality in the United States: 1939–1941 to 1979–1981. *Neurology*. 1993;43:1839–1851.
3. Feinleib M, Ingster L, Rosenberg H, Maurer J, Sing G, Kochanek K. Time trends, cohort effects, an geographic patterns in stroke mortality: United States. *Ann Epidemiol*. 1993;3:458–465.
4. Roccella EJ, Lenfant C. Regional and racial differences among stroke victims in the United States. *Clin Cardiol*. 1989;12:18–22.
5. Heyman A, Tyroler HA, Cassel JC, O'Fallon WM, Davis L, Muhlbaier L. Geographic differences in mortality from stroke in North Carolina, 1: analysis of death certificates. *Stroke*. 1976;7:41–45.
6. Wing S, Casper M, Davis WB, Pellom A, Riggan W, Tyroler HA. Stroke mortality maps: United States whites aged 35–74 years, 1962–1982. *Stroke*. 1988;19:1507–1513.
7. Pickle LW, Mungiole M, Gillum RF. Geographic variation in stroke mortality in blacks and whites in the United States. *Stroke*. 1997;28: 1639–1647.
8. Howard G, Anderson R, Johnson NJ, Sorlie P, Russell G, Howard VJ. An evaluation of social status as a contributing factor to the stroke belt region of the United States. *Stroke*. 1997;28:936–940.
9. Gillum RF, Sempos CT. The end of the long-term decline in stroke mortality in the United States? *Stroke*. 1997;28:1527–1529.
10. Shahar E, McGovern PG, Pankow JS, Doliszny KM, Smith MA, Blackburn H, Luepker RV. Stroke rates during the 1980s: the Minnesota Stroke Survey. *Stroke*. 1997;28:275–279.
11. Howard G. Decline in stroke mortality in North Carolina: description, predictions, and a possible underlying cause. *Ann Epidemiol*. 1993;3: 488–492.
12. Cooper R, Sempos C, Hsieh SC, Kovar MG. Slowdown in the decline of stroke mortality in the United States, 1978–1986. *Stroke*. 1990;21: 1274–1279.
13. Casper ML, Wing S, Anda RF, Knowles M, Pollard RA. The shifting stroke belt: chances in the geographic pattern of stroke mortality in the United States, 1962 to 1988. *Stroke*. 1995;26:755–760.
14. Wegman EJ. Kernel estimators. In: Kotz S, Johnson NL, eds. *The Encyclopedia of Statistical Sciences*. New York, NY: John Wiley & Sons; 1983;369–370.
15. Howard G. County-specific estimation of the Behavioral Risk Factor Surveillance System (BRFSS) with application to physical inactivity and cigarette smoking in North Carolina. In: *1998 North Carolina Cardiovascular Disease Data Summit: Findings and Recommendations for Surveillance and Evaluation*. Raleigh, NC: Cardiovascular Health Data Unit, Division of Community Health, North Carolina Department of Health and Human Services for the North Carolina Heart Disease and Stroke Prevention Task Force; December 1998.
16. Iso H, Jacobs DR Jr, Goldman L. Accuracy of death certificate diagnosis of intracranial hemorrhage and nonhemorrhagic stroke: the Minnesota Heart Survey. *Am J Epidemiol*. 1990;132:993–998.

Editorial Comment

The Decline in Stroke Mortality: An Ending or a Never-Ending Story?

The decline in mortality from cardiovascular diseases, including stroke, in Western countries is fascinating. In the preceding article, Howard and his collaborators add a new important chapter to the story. The width of the stroke belt in the southeastern parts of United States (with the buckle of the belt in Georgia and the two Carolinas) is now being reduced. Instead, a cap has been put on in the northeast, with Oregon and Washington emerging as states with high stroke mortality relative to the national average. The gradients in stroke mortality between blacks and whites continue to diminish, but, if anything, they are increasing between different geographical regions across the United States. Most challenging, the authors estimate, based on the apparent slowing of decline, a final steady state level of stroke mortality that each region in the United States is now approaching.

Intuitively it would be easy to agree with Howard et al that stroke mortality cannot continue to decline forever; stroke will not be eradicated. A similar leveling off of stroke mortality also occurred during the 1990s in Canada and Japan.[1,2] However, epidemiological data on stroke mortality are usually given as age-specific rates. A shift of stroke fatalities toward higher ages, not an implausible development, would be reflected in lower age-specific mortality rates. Even if the decline in stroke mortality is affecting all age groups, as it seems to be in some populations,[3] the demographic development in aging societies may still result in a constant or even increasing total number of stroke deaths in the population.

In the search of forces driving the decline in stroke mortality in Western countries, 2 basic questions need be answered. Are the changes real or do they merely reflect more

accurate diagnostic procedures over time? If they are real, are they caused by a lower risk of being afflicted by stroke (ie, declining incidence) or improved survival (ie, declining case fatality)?

The first question: Can we trust official vital statistics about secular trends in stroke mortality? The few validations of the official stroke mortality data in the United States over time suggest a change in death certificate coding practices for stroke from around 1970 to the mid-1980s.[4,5] During this time, the sensitivity of a stroke diagnosis appearing on the death certificate increased, ie, fewer stroke deaths were being missed[5]—the rate of stroke mortality decline could actually have been even greater than what official data showed. Thus, even if changes in coding practices may have affected the accuracy of official stroke mortality data in the United States over time, it is highly unlikely that they can explain but a small part of the marked decline that occurred from 1970 to the early 1990s. To what extent improved accuracy of death certificate diagnoses has contributed to the apparent end of stroke mortality decline in the US during the 1990s has not been explored.

The ongoing decline in stroke mortality reported by official statistics in many other industrialized countries also seems real. In the West European populations covered by the WHO MONICA Project, official vital statistics on stroke mortality have been found to be reasonably accurate.[6]

So, the decline in stroke mortality is real, even if the exact magnitude of the decline may be uncertain. The next question, then, is: Does the decline reflect lower incidence, lower case fatality, or both?

Community-based longitudinal studies performed in Minnesota[7,8] and Massachusetts[9] suggest that stroke incidence rates have been essentially unchanged in the United States during the past 2 decades (although data for the most recent years are lacking). This is not surprising, because there has been little recent progress in the control of risk factors, such as hypertension, smoking, and physical inactivity.[10]

It follows that reduced case fatality rates must have been driving the decline in stroke mortality that occurred at least up to the beginning of the 1990s. Improved short-term and long-term survival after stroke has been best documented in the Rochester, Minn, and the Pawtucket, RI, studies.[7,9] The Rochester investigators have also shown that there has been no further decline in case fatality rates during the last decade, in parallel with the end of decline of stroke mortality.[7]

The United States has not been unique in having had declining stroke mortality despite unchanged incidence rates. In fact, the same pattern has been present in most West European population studies and in New Zealand (for review, see Reference 11[11]). A definite decline in stroke incidence rates has been documented only in Finland,[12] Australia,[13] and Japan.[14] In the multinational WHO MONICA Project, covering 14 populations in 11 countries, change in case fatality was usually a much stronger predictor of stroke mortality trends than changes in incidence rates.[15] In Russia and Lithuania, with rapid increases in stroke mortality, this could be ascribed

entirely to increased case fatality in the first weeks after stroke onset.[15]

There are 2 important practical lessons from the observation that case fatality is a strong determinant of stroke mortality trends in the population. The first is that with (1) improved survival, (2) constant age-specific stroke incidence, and (3) demographic changes with more people in stroke-prone ages, the burden of stroke on the community and the healthcare system will increase. Obviously, this development urges more determined efforts to prevent first-ever and recurrent strokes. It also mandates improved rehabilitation so that fewer stroke victims are left severely disabled.

The second lesson is that what we do as stroke clinicians matters not only for the individual patient but also has a major impact at the population level (contrary to what some public health experts believe). If case fatality/survival after stroke is so important for stroke mortality rates, it is somewhat difficult to accept the concept of a definite "floor" for stroke mortality, suggested by Howard et al. Their mathematical modeling is based on the development in the past. For an optimistic clinician, it seems that major breakthroughs in acute treatment and secondary prevention of stroke could well overthrow the projections. As shown in the article by Howard et al, the decline in stroke mortality in the United States has, in relative terms, been as rapid in populations starting with low mortality rates as in those starting with high rates. It is equally encouraging that in France and Switzerland, with the lowest stroke mortality rates in Europe (similar to those of the United States), there are no signs that the decline is leveling off.[1,2] As long as there are marked differences in stroke mortality within the United States, by region and socioeconomic class,[16] it is difficult to accept that the leveling off of stroke mortality must be the end of the story.

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References

1. OECD Health Data. Comparative analysis of 29 countries. *Database Paris*. 2000.
2. Sarti C, Rastenyte D, Cepaitis Z, Tuomilehto J. International trends in mortality from stroke, 1968 to 1994. *Stroke*. 2000;31:1588–1601.
3. Peltonen M, Asplund K. Age-period-cohort effects on stroke mortality in Sweden 1969–1993 and projections up to the year 2003. *Stroke*. 1996; 27:1981–1985.
4. Barker WH, Schiesser M, Cheek PR. Changes in certification of cause of death among confirmed strokes, 1967-71 and 1981-85. *Stroke*. 1998; 29:283. Abstract.
5. Iso H, Jacobs DR, Jr, Goldman L. Accuracy of death certificate diagnosis of intracranial hemorrhage and nonhemorrhagic stroke: the Minnesota Heart Survey. *Am J Epidemiol*. 1990;132:993–998.
6. WHO MONICA Project (prepared by Asplund K, Bonita R, Kuulasmaa K, et al). Multinational comparisons of stroke epidemiology: evaluation of case ascertainment in the WHO MONICA Stroke Study. *Stroke*. 1995;26:355–360.
7. Brown RD, Whisnant JP, Sicks JD, O'Fallon WM, Wiebers DO. Stroke incidence, prevalence, and survival: secular trends in Rochester, Minnesota, through 1989. *Stroke*. 1996;27:370–372.
8. Luepker RV, Rastam L, Hannan PJ, Murray DM, Gray C, Baker WL, Crow R, Jacobs DR Jr, Pirie PL, Mascioli SR, Mittelmark MB, Blackburn

H. Community education for cardiovascular disease prevention: morbidity and mortality results from the Minnesota Heart Health Program. *Am J Epidemiol*. 1996;144:351–362.

9. Derby CA, Lapane KL, Feldman HA, Carleton RA. Trends in validated cases of fatal and nonfatal stroke, stroke classification, and risk factors in southeastern New England, 1980 to 1991: data from the Pawtucket Heart Health Program. *Stroke*. 2000;31:875–881.

10. Cooper R, Cutler J, Desvigne-Nickens P, Fortmann SP, Friedman L, Havlik R, Hogelin G, Marler J, McGovern P, Morosco G, Mosca L, Pearson T, Stamler J, Stryer D, Thom T. Trends and disparities in coronary heart disease, stroke, and other cardiovascular diseases in the United States: findings of the national conference on cardiovascular disease prevention. *Circulation*. 2000;102:3137–3147.

11. Asplund K, Stegmayr B, Peltonen M. From the twentieth to the twenty-first century: a public health perspective on stroke. In: Ginsberg MD, Bogousslavsky J, eds. *Cerebrovascular Disease: Pathophysiology, Diagnosis and Management*. Oxford, UK: Blackwell Science; 1998:901–918.

12. Tuomilehto J, Rastenyte D, Sivenius J, Sarti C, Immonen-Raiha P, Kaarsalo E, Kuulasmaa K, Narva EV, Salomaa V, Salmi K, Torppa J. Ten-year trends in stroke incidence and mortality in the FINMONICA Stroke Study. *Stroke*. 1996;27:825–832.

13. Jamrozik K, Broadhurst RJ, Lai N, Hankey GJ, Burvill PW, Anderson CS. Trends in the incidence, severity, and short-term outcome of stroke in Perth, Western Australia. *Stroke*. 1999;30:2105–2111.

14. Morikawa Y, Nakagawa H, Naruse Y, Nishijo M, Miura K, Tabata M, Hirokawa W, Kagamimori S, Honda M, Yoshita K, Hayashi K. Trends in stroke incidence and acute case fatality in a Japanese rural area: the Oyabe study. *Stroke*. 2000;31:1583–1587.

15. Asplund K, Tolonen H, Sarti C, Mähönen M, Stegmayr B, Vanuzzo D, Rastenyte D, Tuomilehto J, Kuulasmaa K, for the WHO MONICA Project. What determines long-term changes in stroke events and mortality? Ten-year trends in risk factors, event rates and case fatality in 15 populations in the WHO MONICA Project. *Cerebrovasc Dis*. 2000; 10(suppl 1):2. Abstract.

16. Howard G, Anderson RT, Russell G, Howard VJ, Burke GL. Race, socioeconomic status, and cause-specific mortality. *Ann Epidemiol*. 2000; 10:214–223.