New Considerations in Analyzing Stroke and Heart Disease Mortality Trends

The Year 2000 Age Standard and the International Statistical Classification of Diseases and Related Health Problems, 10th Revision

R.F. Gillum, MD

Background—Monitoring of trends and patterns of stroke mortality will be of utmost importance in the coming decade. Two innovations in vital statistics may complicate this task and must be brought to the attention of both researchers and readers of research reports: the new Year 2000 Age Standard and the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10).

Summary of Review—For cerebrovascular diseases, the age-adjusted death rate is 2.4 times higher with the use of the year 2000 standard than with the use of the old 1940 standard. However, if rates for all years are computed with the use of the same age standard, the percent change from 1979 to 1995 is similar according to the 1940 standard (−35.8%) or the year 2000 standard (−34.3%). Another important effect of the change to the year 2000 standard is to reduce black/white differentials in age-adjusted death rates. Major discontinuities are not observed for mortality trends in cerebrovascular disease or heart disease between International Classification of Diseases, Ninth Revision (ICD-9) (1979–1998) and ICD-10 (1999 and following years) classifications.

Conclusions—All data users must exercise caution to specify the age standard used when assessing or presenting age-adjusted rates over time or between groups. The comparability of ICD codes chosen for years before 1999 versus 1999 or following years must be checked to distinguish changes due to coding from true changes in mortality levels.

Stroke is the third leading cause of death in the United States.1 A decline in the age-adjusted death rate for nonwhite females began in 1924, for nonwhite males in 1930, and for European Americans by 1918.2 The rate of decline accelerated in the 1970s, likely because of improved hypertension control, but slowed in the 1980s for reasons that remain unclear.3 Recently published statistics suggest that the long-term decline in stroke mortality rates in the United States may have ceased in the 1990s.4 Since 1914, higher mortality from stroke in US blacks than whites has been documented by vital statistics, with differentials maintained as diagnostic technology developed over the century.1–6 Longstanding differences in stroke mortality rate levels between US regions have also been documented.2,6 Thus, continued monitoring of trends and patterns of stroke mortality will be of utmost importance in the coming decade. However, 2 innovations in vital statistics may complicate this task and should be brought to the attention of both researchers and readers of research reports: the Year 2000 Age Standard and the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10). This report will examine both and assess their potential impact on the monitoring of trends and racial patterns in stroke mortality.

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Published vital statistics data from the US National Center for Health Statistics (NCHS) for the years 1979–1997 were reviewed. The rubric for stroke used was 430 to 438 of the International Classification of Diseases, Ninth Revision (ICD-9). Standard methods of analysis used are detailed elsewhere.1 Briefly, race-specific numbers of deaths from NCHS and population estimates from the US Bureau of Census were used to compute death rates. Age standardization was performed by the direct method with the 1940 US total population standard or the projected year 2000 population standard (based on projections prepared in spring 1998 by the US Bureau of the Census).7 As recommended, 11 age groups in current use were used to calculate age-adjusted rates. Expanding the number of age groups by disaggregating the category ≥85 years to 85 to 94 years and ≥95 years has been shown to produce a difference of <1% in adjusted rates compared with rates obtained with the use of 11 groups.8 In addition, a detailed search of the medical literature since 1990 was performed.
with the use of the MEDLINE and Locator Plus databases of the National Library of Medicine.

The Year 2000 Age Standard

Because of the effect of changing population age composition over time and the cumbersome nature of comparing many age-specific death rates, age-adjusted death rates have long been used for assessing trends in population mortality rates as well as for comparing groups. Extensive discussions of this methodology have been published elsewhere.\(^7\)\(^8\)\(^9\) Computed by the direct method, the age-adjusted death rate is a weighted average of age-specific death rates. The weights are the proportions of a standard population by age. Since 1943, the US government has used the 1940 standard million population for this purpose. On the basis of recommendations of 2 expert workshops, the Department of Health and Human Services (DHHS) has adopted a new standard, the year 2000 population, beginning with data year 1999.\(^7\)\(^8\)\(^10\)\(^11\) Advantages of the new standard include improved consistency with the crude death rate, consistency among agencies within DHHS, and enhanced public perceptions of appropriateness of the chosen standard.\(^7\)\(^12\)\(^13\)\(^14\) The US Bureau of Census prepared the projected population age distribution for the year 2000, and this was converted by the NCHS to a standard million population by dividing the age-specific populations by the total population and multiplying by 1 million (Table 1). The use of the projected age distribution allowed application and evaluation of the new standard years before the enumerated year 2000 population from the April 2000 census, which should not differ in any practically important way from the projected population for purposes of age adjustment, would be available.\(^7\)\(^8\)\(^12\)\(^12\)

For cerebrovascular disease (ICD-9 430 to 438), heart disease (ICD-9 390 to 398, 402, 404 to 429), and atherosclerosis (ICD-9 440), there is a major effect on the magnitude of the age-adjusted rates of the change to the year 2000 standard population.\(^7\) This is because deaths from these causes occur disproportionately at older ages and because the year 2000 population shows a higher proportion of persons in older age groups compared with 1940, eg, the proportion aged ≥65 years doubled.\(^7\) For example, for cerebrovascular diseases, the age-adjusted death rate for 1995 was 2.4 times higher with the use of the year 2000 standard (63.9 per 100 000) than with the use of the 1940 standard (26.7 per 100 000). Similar effects are seen for heart disease and atherosclerosis and death from all causes. The standard errors of age-adjusted death rates will increase in proportion to the increase in magnitude of the rates; however, relative standard errors will change little.\(^11\)

All data users must exercise caution to specify the standard population used when assessing or presenting any age-adjusted rate to compare rates over time or between groups. To characterize the “burden” of disease in the United States or a state, the crude death rate, age-specific death rate(s), or number of deaths is more appropriate.\(^12\) Data users must also be prepared to explain to audiences or the media the reason for apparent discrepancies between magnitude of rates computed with the year 2000 standard and previously published rates computed with the 1940 standard or other standards.

In addition to using the year 2000 standard for age-adjusted rates for data years 1999 and later, all DHHS components and states as well as data users will likely recompute age-adjusted rates for 1979–1998 using the year 2000 standard to facilitate trend analyses. Figure 1 shows the trends in age-adjusted death rates for cerebrovascular disease with the use of the 1940 and 2000 standard populations for the United States in 1979–1995.\(^7\) Although the choice of age standard affects trends for some causes of death, for cerebrovascular disease the relative trends are virtually the same regardless of standard. The percent change from 1979 to 1995 was −35.8% with the use of the 1940 standard and −34.3% with the use of the year 2000 standard. This occurred because trends for various age-specific rates were roughly parallel over the period (age 25 to 64 years, −39.1%; age ≥65 years, −28.2%). Figure 2 shows 1995 rates as percentages of 1979 rates by age. Nevertheless, data users must be sure to use the same standard population to compute age-adjusted rates for all years in any percent change analysis. The published standard million for the year 2000 (Table 1) can be used as needed by data users to compute age-adjusted rates, as previously described.\(^7\)\(^8\) As has been suggested, a good compromise between presenting age-specific and age-adjusted rates is to present age-adjusted rates for one or a few broad age bands, eg, 25 to 64 and ≥65 years.\(^5\)\(^10\)

Another important effect of the change to the year 2000 standard will be to reduce apparent black/white differentials in death rates for cerebrovascular diseases, heart disease, atherosclerosis, and all causes.\(^7\)\(^8\) This occurs because mortality race ratios for these causes are much lower at ages ≥65 years than at

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**TABLE 1. Projected Year 2000 US Population and Proportion Distribution by Age**

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Population</th>
<th>Proportion</th>
<th>Standard Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>274 634 000</td>
<td>1.0000000</td>
<td>1 000 000</td>
</tr>
<tr>
<td>&lt;1</td>
<td>3 795 000</td>
<td>0.013818</td>
<td>13 818</td>
</tr>
<tr>
<td>1–4</td>
<td>15 192 000</td>
<td>0.055317</td>
<td>55 317</td>
</tr>
<tr>
<td>5–14</td>
<td>39 977 000</td>
<td>0.145565</td>
<td>145 565</td>
</tr>
<tr>
<td>15–24</td>
<td>38 077 000</td>
<td>0.138646</td>
<td>138 646</td>
</tr>
<tr>
<td>25–34</td>
<td>37 233 000</td>
<td>0.135573</td>
<td>135 573</td>
</tr>
<tr>
<td>35–44</td>
<td>44 659 000</td>
<td>0.162613</td>
<td>162 613</td>
</tr>
<tr>
<td>45–54</td>
<td>37 030 000</td>
<td>0.134834</td>
<td>134 834</td>
</tr>
<tr>
<td>55–64</td>
<td>23 961 000</td>
<td>0.087247</td>
<td>87 247</td>
</tr>
<tr>
<td>65–74</td>
<td>18 136 000</td>
<td>0.066037</td>
<td>66 037</td>
</tr>
<tr>
<td>75–84</td>
<td>12 315 000</td>
<td>0.044841</td>
<td>44 841</td>
</tr>
<tr>
<td>≥85</td>
<td>4 259 000</td>
<td>0.015508</td>
<td>15 508</td>
</tr>
</tbody>
</table>

Source: National Vital Statistics Reports.\(^7\)

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**Figure 1.** Trends in age-adjusted death rates for cerebrovascular disease with the use of the 1940 and 2000 standard populations: United States, 1979–1995. Source: NCHS.\(^7\)
The 10th Revision of the ICD

On January 1, 1993, the ICD-10 became available for implementation. In preparation since 1983, it was designed to replace the ICD-9. Innovations included an alphanumeric coding scheme of 1 letter followed by 3 numbers, intended to enlarge the number of categories from approximately 5000 to approximately 8000, provide a better balance between the content of the chapters, and leave room for future additions and changes without renumbering categories. The Supplementary Classifications of External Causes of Injury and Poisoning (the E code) and Supplementary Classification of Factors Influencing Health Status and Contact With Health Services (the V code) from ICD-9 were incorporated as chapters in ICD-10. Some of the coding rules and rules for selecting the underlying cause of death were changed. A revised, more descriptive title was adopted. In the United States, ICD-10 has been implemented for deaths occurring in 1999. Preliminary data for 1999 began to appear in 2001, for example, in the annual publication Health United States. ICD-10 has already been implemented for earlier data years in a few countries. For morbidity data such as hospital discharge data, careful study and planning are ongoing in preparation for the clinical modification (CM) of the ICD (ICD-10-CM) to be implemented in the United States by NCHS within the next few years, replacing ICD-9-CM, which is currently in effect in the United States.

Table 2 shows the categories under both ICD-10 and ICD-9 for selected causes, including cerebrovascular disease, ischemic heart disease, and atherosclerosis. Transient cerebral ischemic attacks have been moved from diseases of the circulatory system (ICD-9 code 435) to diseases of the nervous system (ICD-10 codes G45.8 and G45.9). The single code for acute myocardial infarction (ICD-9 code 410) was expanded to 6 codes (I21.0 to I21.4, I21.9), which specify the site of infarction. A change in the rules for direct sequels makes pneumonia much less likely to be selected as the underlying cause of death under ICD-10 than under ICD-9. Thus, a small number of cerebrovascular diseases and heart diseases are more likely to be selected as the underlying cause. Changes in the rules that regulate how ill-defined conditions are handled cause unspecified cardiac arrest (ICD-10 I46.9) to be considered an ill-defined condition. Changes in the rules for highly improbable sequences make it possible for intracranial hemorrhage to be classified as due to certain heart diseases (ICD-10 I05 to I08, I19.1, I33 to I38).

As suggested by the categories for cerebrovascular disease and heart disease, major shifts in the statistical classification, such as occurred between the eighth and ninth revisions for ischemic heart disease, are not expected. However, as for each new revision, extensive comparability studies are under way to quantify the impact of the coding change. In the main study, 1.8 million deaths from 1996 (80% of total resident deaths) have been coded by an automated system with the use of both ICD-9 and ICD-10, and preliminary results have been published. When an additional approximately 400 000 codes that cannot be handled by the automated system are manually coded, final comparability ratios (deaths coded to the cause by ICD-10/deaths coded to the cause by ICD-9) will be computed and published for 113 causes in both print and electronic form. Multiplying the number of ICD-9 deaths by the estimated comparability ratio will yield the expected number of deaths under ICD-10.

Preliminary data based on this nonrandom sample of mortality records (n=1 852 671) indicated a comparability ratio of 1.06 for cerebrovascular diseases, a net increase of...
6% allocated to underlying cause cerebrovascular disease with ICD-10 compared with ICD-9.18 This increase was due to the change in the rule for coding sequels, specifically pneumonia. Most of the additional deaths coded to cerebrovascular diseases in ICD-10 were classified as pneumonia in ICD-9, both causes having been listed on the death certificate. The comparability ratio was 0.9858 for diseases of the heart, 0.9990 for ischemic heart disease, 0.9887 for acute myocardial infarction, and 0.9637 for atherosclerosis (Table 2). Small shifts away from heart disease occurred because of the rule change that considered unspecified cardiac arrest as an ill-defined condition not to be considered in choosing the underlying cause of death if another more specific condition was listed. This decrease was partially offset by the addition of deaths coded pneumonia under ICD-9 but considered a sequel of heart disease under ICD-10. Thus, discontinuities in numbers of deaths and death rates between 1998 and 1999 will be relatively small for stroke and heart disease.

However, changes in coding rules will have major impacts on some causes of death that can be considered sequels or complications of another cause, such as pneumonia.18 As mentioned above, such deaths must be coded to the other listed cause if possible in ICD-10. Hence, the comparability ratio for pneumonia was only 0.6957. Thus, before undertaking analyses of mortality trends for periods including both ICD-9 and ICD-10 classifications (1999 and following years), the comparability of codes chosen for each period must to checked to distinguish discontinuities due to coding changes from true changes in mortality. Interestingly, there was no change in rank of the 5 leading causes of death in 1996, including diseases of the heart (ranked first) and cerebrovascular diseases (ranked third) when coded with the use of ICD-9 or ICD-10. However, changes in rank did occur in lower-ranking causes.18

The effect of the change to ICD-10 can be assessed by multiplying the number of deaths or the death rate for any year during 1979–1998 with the use of ICD-9 by the comparability ratio to obtain the corrected number or rate, which should approximate the rate with the use of ICD-10 and hence be comparable with published rates for 1999 and following years. Preliminary comparability ratios may safely be used until the final ratios are published. Caution must be used, however, when the national ratios are applied to demographic and geographic subgroups.

**US Goals for 2000 and 2010**

Given the growing burden of disease for stroke,5–20 national research and stroke control efforts are vital. Through an extensive consultative process in the late 1980s, the US DHHS set a target goal for age-adjusted stroke mortality in blacks for the year 2000 of a nearly 50% decline from the 1987 level.21 The 1996 rate for blacks was well short of the goal for 2000. Since both the new standard population for age adjustment and ICD-10 are being implemented for data years 1999 and 2000, the final evaluation of success in meeting mortality goals for health promotion and disease prevention for the year 2000 will take these changes into account when rates for these years are compared with targets set with the use of the 1940 or the estimated 2000 standard population and ICD-9.22,23

A similar process has set goals for health promotion and disease prevention for the year 2010.23,24 Increasing the years and quality of healthy life and eliminating (not merely reducing) health disparities among population groups are the overarching goals. In moving toward these 2 goals in the United States, several health objectives relating to stroke were established for the year 2010.23,24 Objectives for stroke mortality reductions by 2010 are expressed in terms of age-adjusted rates computed with the use of the year 2000 age standard and ICD-9 and ICD-10. In addition, baseline data for 1997 and 1998 were recomputed with the use of the year 2000 population standard for ease of comparison with 1999 and later data. Targets for age-adjusted stroke mortality rate are 48 per 100,000 for all Americans, white and black, a 20% improvement from the baseline of 60 per 100,000 in 1998 (Objective 12-7, Reduce stroke deaths).24

**Table 2. Codes for Selected Causes of Death According to ICD-10 and ICD-9**

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>ICD-10 Codes*</th>
<th>ICD-9 Codes</th>
<th>CR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diseases of heart</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ischemic heart diseases</td>
<td>I00–I09, I11, I13, I20–I51</td>
<td>390–398, 402, 404, 410–429</td>
<td>0.9858</td>
</tr>
<tr>
<td>Acute myocardial infarction</td>
<td>I20–I25</td>
<td>410–414, 429.2</td>
<td>0.9990</td>
</tr>
<tr>
<td>Other acute ischemic heart disease</td>
<td>I24</td>
<td>411</td>
<td>1.0110</td>
</tr>
<tr>
<td>Other forms of chronic ischemic heart disease</td>
<td>I20, I25</td>
<td>412–414, 429.2</td>
<td>1.0054</td>
</tr>
<tr>
<td>Atherosclerotic cardiovascular disease, so described</td>
<td>I25.0</td>
<td>429.2</td>
<td>1.0488</td>
</tr>
<tr>
<td>All other forms of chronic ischemic heart disease</td>
<td>I20, I25.1–I25.9</td>
<td>412–414</td>
<td>0.9935</td>
</tr>
<tr>
<td>Heart failure</td>
<td>I50</td>
<td>428</td>
<td>1.0410</td>
</tr>
<tr>
<td>Cerebrovascular diseases</td>
<td>I60–I69</td>
<td>430–434, 436–438</td>
<td>1.0588</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>I60</td>
<td>430</td>
<td>NA</td>
</tr>
<tr>
<td>Intracerebral and other intracranial hemorrhage</td>
<td>I61–I62</td>
<td>431–432</td>
<td>NA</td>
</tr>
<tr>
<td>Cerebral infarction</td>
<td>I63</td>
<td>434</td>
<td>NA</td>
</tr>
<tr>
<td>Stroke, not specified as hemorrhage or infarction</td>
<td>I64</td>
<td>436</td>
<td>NA</td>
</tr>
<tr>
<td>Other cerebrovascular diseases and their sequelae</td>
<td>I67, I69</td>
<td>433, 434, 437–438</td>
<td>NA</td>
</tr>
<tr>
<td>Atherosclerosis</td>
<td>I70</td>
<td>440</td>
<td>0.9637</td>
</tr>
</tbody>
</table>

CR indicates estimated comparability ratio; NA, not available.

*Source: NCHS.19
Regarding eliminating disparities, the effects of the year 2000 age standard on the age-adjusted rates of cerebrovascular disease deaths in blacks and whites and on mortality race ratios are of particular concern. Use of the year 2000 age standard reduces the apparent racial disparity in age-adjusted rates.25 Although even with the use of the year 2000 standard it seems unlikely that the black/white disparity in age-adjusted rates can be eliminated by 2010 (1997 age-adjusted rates: blacks, 82 per 100 000; whites, 60 per 100 000), it will be important to continue to emphasize the large disparities in age-specific rates at younger ages and to target programs accordingly. For example, the rate of years of life lost before age 75 years due to stroke in blacks was triple that of whites in 1995. Another complication beyond the scope of this report is the possible effect of the new method of ascertain-
ing race used in the 2000 census on race-specific death rates.26

Conclusions
Mortality statistics and the techniques for their analysis have developed in parallel with the public health movement over the past 150 years.27,28 Such statistics still form the cornerstone of the public health database for monitoring the health of populations. This is particularly true for cerebrovascular disease, for which prevalence and incidence measures of morbidity are frequently lacking for analysis of trends and racial and geographic variations.3–6 Thus, developments affecting proper use and interpretation of mortality statistics for cerebrovascular disease are of concern to all users of these data. Use of the new year 2000 standard population for age adjustment will affect the magnitude of age-adjusted rates but when used appropriately should pose few difficulties in the assessment of trends in cerebrovascular mortality when the same standard is used for all years in question. Comparisons of cerebrovascular mortality by race require examination of age-specific as well as age-adjusted rates. The change from ICD-9 to ICD-10 should have minimal effects on use and interpretation of cerebrovascular mortality data once the comparable rubrics in both classifications become familiar. However, further research is need in several areas: examination of age-specific rates by sex and race at ages $\geq$85 years; examination of trends in age-specific rates by sex and race; race-specific ICD-10/ICD-9 comparability ratios; and state-specific ICD-10/ICD-9 comparability ratios.

Cerebrovascular disease and heart disease continue to be leading causes of mortality in the United States, with major disparities among races and regions.27 Continued careful monitoring of mor-
tality trends and patterns by race and region are needed. Two new developments that affect use of mortality data for these purposes are the implementation of a new year 2000 standard population for age adjustment and ICD-10. To avoid difficulties in using, interpreting, and communicating age-adjusted mortality rates for 1999 and beyond, data users should become familiar with both innovations and their effects on levels, trends, and racial patterns of rates.

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Trends in Stroke Mortality: The Impact of the Year 2000 Age Standard and the International Statistical Classification of Diseases and Related Health Problems, 10th Revision

Understanding the implications of using weighted average age-specific death rates for the year 2000 population and the International Classification of Diseases, 10th Revision (ICD-10) codes is essential for the continued monitoring of trends and patterns of mortality. Gillum’s report examines the potential impact of these innovations on monitoring stroke mortality trends. Researchers and readers assessing age-adjusted rates need to specify carefully the standard population when comparing across time or groups. Furthermore, journal editors and reviewers will need to emphasize the implementation of these innovations to ensure a smooth and quick transition of acceptance of these changes. Finally, data users must be prepared to explain to the media and lay public why discrepancies exist between magnitude of stroke rates with year 2000 standards versus previously used year 1940 standards and the differences between ICD-10 and ICD-9.

Continued monitoring of stroke mortality patterns is essential because we are far from reaching the Healthy Year 2010 goal of reducing stroke mortality by 20%.1 In fact, there is evidence for a marked decrease in the rate of decline in stroke mortality in the 1990s.2,3 Potential explanations for the slowing of declines in stroke mortality may involve changes in the control of hypertension. Whereas data from a national examination survey offer no evidence of deterioration in hypertension detection and control,4 rates of hypertension control have not increased (29% to 27.4%) between NHANES III (phase I) 1988–1991 and NHANES III (phase 2) 1992–1994.5 One of the best chances to increase the rate of decline in stroke mortality may be to redouble efforts to achieve the goal for the year 2010 of increasing to at least 50% the proportion of people with high blood pressure whose blood pressure is under control (<140 mm Hg systolic and 90 mm Hg diastolic).1

In terms of implementing age-specific death rates for the year 2000 population, examining the number of age groups by 5-year intervals may be required to ensure that the stroke mortality trend is consistent among all age groups and racial/ethnic groups. As the US population ages and experiences more chronic diseases including increasing diabetes, ischemic heart disease, atrial fibrillation, and heart failure, the prevalence of stroke mortality and morbidity is likely to increase. However, increased use of old (ie, aspirin and other antithrombotic agents) and new treatments will require continued examination of the trends and patterns of not only stroke mortality but also stroke morbidity. Data users becoming familiar with the implementation of the new year 2000 standard population for age adjustment and ICD-10 will facilitate the use, interpretation, and communication of this information. Furthermore, these innovations will be necessary to improve statistical modeling approaches to provide estimates of the potential effect of trends in medical care on stroke mortality and morbidity and of the potential costs and benefits for primary and secondary prevention programs to reduce stroke risk factors, and to promote more widespread practice of early stroke care.

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