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Population shifts and the future of stroke: forecasts of the future burden of stroke

George Howard¹ and David C. Goff²

¹Department of Biostatistics, UAB School of Public Health, Birmingham, Alabama

²Office of the Dean, Colorado School of Public Health, Aurora, Colorado

Abstract

Population distribution estimates by age and race/ethnicity from the U.S. Census Bureau for the years 2010 and 2050 were combined with estimates of stroke incidence from population-based surveillance studies to forecast the distribution of incident stroke cases for the years 2010 and 2050. Over these 40 years, the number of incident strokes will more than double, with the majority of the increase among the elderly (age 75+) and minority groups (particularly Hispanics). These increases are likely to present major logistical, scientific, and ethnical issues in the near future.

Keywords

stroke; incidence; aging; race; projections

Introduction

Quotes regarding the “art” of forecasting strongly underscore the consistency in their imprecision, for example, “He who lives by the crystal ball soon learns to eat ground glass” (credited to Edgar R. Fiedler). However, anticipated changes in the population shifts in age and ethnic distribution are likely to have a profound effect on the number of strokes and the demographic characteristics of stroke victims. These shifts imply the need for resource planning to care for stroke patients, and also for the need to design epidemiological studies and clinical trials that will provide evidence-based guidance for the prevention of stroke and care for the stroke patients of the future. In this paper, population changes available from the U.S. Census Bureau are combined with available data on stroke incidence rates to forecast the number of stroke events and the demographic characteristics (gender and race/ethnicity) of stroke patients over the next 40 years in the United States.

Forecasts

Population changes

The U.S. Census Bureau provides data on the age-specific distribution for non-Hispanic whites,¹ blacks,² Hispanics,³ Asian and Pacific Islanders,⁴ and Native Americans and Alaska Natives⁵ for the U.S. population in 2010 as well as forecasts of the distribution over the next 40 years (see Fig. 1). Aspects found in the left panel of Figure 1, showing the age

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Address for correspondence: George Howard, Department of Biostatistics; Ryals Building Room 327, UAB School of Public Health, 1665 University Blvd. Birmingham, AL 35294-0022. ghoward@uab.edu.

Conflicts of interest

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distribution in the year 2010, will have a powerful effect on the future distribution of stroke-events. First, there are a total of ~120,789,000 people aged 45 and over (i.e., stroke-prone ages). Second, there is a (predominately white) bulge of the population between ages 45–49 and 65–69 representing the “baby boomer” cohort, with a smaller number of people at both younger and older ages. In a related observation, there are currently relatively few elderly people in the population, of those aged 45+ (i.e., in the stroke-prone ages), only 4.7% (5,735,000/120,789,000) of the population is aged 85+ and 15.5% (18,709,000/120,789,000) is aged 75+. Finally, ethnic minority groups (particularly Hispanics) constitute a relatively larger proportion of the population below ages 50–54 than above. In 2010, 75.0% of the population was white, 10.6% black, 9.6% Hispanic, 4.1% Asian, and 0.8% Native American. Overall, 53.2% of the population over age 45 were women, whereas 60.8% of the population over age 75 were women.

The right panel of Figure 1 shows the U.S. Census estimates for the population in 2050. By this time, the population aged 45+ years is estimated to have increased 53.9% to ~185,943,000 residents. Importantly, over the 40 years the bulge of the population aged 45–49 to 65–69 will have aged to be over age 85, so that among those aged 45+, the proportion over age 85 will have more than doubled to 10.2% (19,005,000/185,943,000), and the proportion over age 75 will have almost doubled to 26.0% (48,357,000/185,943,000). In addition, the more stroke-prone minority (primarily Hispanic) population, currently under age 45, will have now moved into the stroke-prone ages, so that of those aged 45+ the proportion of whites will fall over 20–54.1%, whereas the proportion of Hispanics will more than double to 22.9%, with a smaller approximate 2% increase in the number of blacks to 12.4% (for completeness, the number of Asians will also increase to 8.8%, and the proportion Native Americans will increase to 1.1%). Finally, the proportion of women aged 45+ will remain largely unchanged (52.7%), as will the proportion of women among those aged 85+ (projected to be 60.8%) and the proportion of women among those aged 75+ (projected 57.1%).

As such, over the next 40 years the U.S. population over age 45 is expected to increase by more than 50%. Among those over 45, the proportion of the “oldest old” will approximately double, and the minority representation among those over age 45 is expected to substantially increase. The combination of more people over age 45 shifts toward the most elderly within that group, and an increased representation of minorities are each changes likely to be associated with a higher number of stroke events in the overall population.

Stroke incidence rates

Although stroke mortality has been rapidly falling for more than 50 years (100 years in the United States), it is not clear whether these temporal changes are attributable to a declining incidence of stroke or an improving stroke case fatality.⁶ There are remarkably few sources of data on stroke incidence rates, much less temporal changes in stroke incidence. Early reports from predominately white communities have suggested only a modest decline in stroke incidence that is likely insufficient to account for the dramatic declines in stroke mortality.^{7,8} Recent reports from the Greater Cincinnati/Northern Kentucky Stroke Study (GCNKSS) suggest stroke incidence rates seem to be modestly falling for whites but not for blacks.⁹ To complicate the estimation (and further complicate the forecasting) of stroke incidence rates, there are growing concerns that an increasing prevalence of obesity in the United States (i.e., the “obesity epidemic”) will lead to increased prevalence of hypertension and diabetes, with an increase in the general incidence of cardiovascular disease^{10,11} and stroke in particular.¹² As such, we assumed that future stroke incidence rates would be relatively constant because: (1) it is not at all clear that the falling stroke mortality is attributable to falling incidence, and (2) even if the stroke incidence is in fact falling there

are concerns that increasing obesity and comorbidities could reverse these declines in incidence.

As noted previously, there are remarkably few sources of age–race–sex–specific estimates of incidence of stroke. For whites and blacks, “unpublished” data from GCNKSS available from the American Heart Association Statistical Update were used (see Table 1),⁶ data conveniently provided in 10-year intervals beginning at age 45. These data were used under the assumption that stroke incidence rates for blacks and whites in the greater Cincinnati region are reflective of national stroke incidence rates.

For Hispanics, the most reliable data are from a Mexican American population in the Brain Attack Surveillance in Corpus Christi (BASIC) study.¹³ Although these are the most reliable data available for incidence rates in a Hispanic population, two substantial assumptions must be made for the use of these data in this effort. First, that Hispanic-to-white stroke incidence ratios for Mexican Americans are reflective of ratios based on Hispanics nationwide. Second, Morgenstern *et al.*¹³ did not report incidence rates in the same age strata as for the GCNKSS; hence, assumptions had to be made to “realign” these data to reflect similar age strata (see Table 1). These assumptions were made using a conservative approach. Specifically, Morgenstern reported Hispanic-to-white incidence ratios of 2.04 for ages 45–59, 1.58 for ages 60–74, and 1.12 for ages over 85. For these calculations, the Hispanic-to-white incidence ratio was assumed to be 2.04 for ages 45–54 (because the reported incidence ratio is decreasing, the “true” rate is likely higher in this lower portion of the reported age range), 1.81 for ages 55–65 (calculated as the average of the reported ratios of 2.04 and 1.58 that span these ages), 1.58 for ages 65–74 (the value reported for the ages 60–75 by Morgenstern), 1.12 for ages 75–84 (again, the rate is likely higher for this lower portion of the reported 75+ age strata), and 1.00 for ages 85 and over (conservatively assumed to be the same as whites in the oldest old strata). These Hispanic-to-white incidence ratios were then applied to the estimated white incidence rates provided by the GCNKSS to derive the estimated Hispanic rate for men and women (again, see Table 1).

Finally, although there are cohort studies that do provide estimates, to the authors’ knowledge there are no data available from large population based surveillance studies for stroke incidence in the U.S. Asian/Pacific Islander population or the Native American/Alaska Native population. As such, the incidence rates for these populations were conservatively assumed to be the same as for the white population.

Clearly, these estimates of stroke incidence are made under a number of assumptions that could be questioned. The temporal changes in the distribution of incident stroke events are primarily driven by the immense changes in the demographic distribution of the population described in the previous section. However, confidence in the approach is provided by a similarity in both black-to-white and Hispanic-to-white incidence ratios (and rates) reported by the Northern Manhattan Stroke Study (NOMASS or NOMAS).¹⁴ In addition, to the extent that these estimates rates are incorrect, they are assumed to be constant over the temporal period considered, and as such, the observed differences in the distribution of incident strokes is driven by the large changes in population distributions described earlier.

Stroke incidence forecasts

The forecast of the age–race–sex distribution of the incident stroke is simply the product of the forecast of the population distribution times the estimated incidence rates, and is provided in Figure 2. The panel on the left shows the distribution of the estimated 593,000 strokes occurring in 2010 among individuals above the age 45. These forecasts suggest that only 23% occurred above age 85 and 50% above age 75. In addition, the strokes were predominately occurring among whites (75%), with only 11% in blacks, 11% in Hispanics,

and 4% in the Asian or Native American population. Finally, of all the strokes, 51% were in women and 49% were in men.

These forecasts suggest that by the year 2050 the number of stroke events will expand by 2.25 times to a total of 1,334,000 stroke events. In addition, over one-third (34%) of the stroke events will occur above age 85, and nearly two-thirds (66%) will occur above age 75. In addition, these forecasts suggest that only a slight majority of the strokes will occur in the white population (56%), with the number of stroke events occurring among Hispanics nearly doubling to 24% (from 11% in 2010), with smaller increases in the proportion of strokes in blacks to 12% and other races to 8%. Finally, the gender distribution will tilt slightly more to men, with women having only 49% of the stroke events.

In conclusion, these forecasts suggest that the number of stroke events will dramatically increase, with the majority of the increase in the elderly and minority (particularly Hispanic) populations.

Discussion

These forecasts suggest that the number of stroke events will dramatically increase (more than double!), with the majority of the increase in the elderly and minority (particularly Hispanic) populations. Should this projection hold true, the implications are staggering both logistically, scientifically, and ethically.

Logistically, the increased burden of care of stroke patients on an already stressed healthcare system could be overwhelming. Not only will this burden fall on physicians and hospitals, but also on demand for rehabilitation services and increased nursing home demand. As noted in a report of a Workforce Task Force of the American Academy of Neurology: "Overall, the current ratio of adult neurologists to the population is appropriate, and demand is likely to exceed supply in the next 20 years."¹⁵ Should this forecast (made in the year 2000) be true, the shortage of neurologists to care for the doubling of stroke patients will offer remarkable challenges. The same Task Force report notes immense geographic maldistribution of neurologists, with 2.14 neurologists per 100,000 residents of Mississippi, and 6.62 per 100,000 residents of Massachusetts. Although this report did not focus on geographic shifts in burden of stroke, it is reasonable to assume that the doubling of strokes in the "Stroke Belt" region of the United States with fewer neurologists will be even more difficult to manage logistically.

Scientifically, the explosion of the number of stroke events is precisely in the populations that have been excluded or underrepresented in stroke prevention and treatment clinical trials. Although numerous other examples exist, guidance for the need for revascularization of asymptomatic patients with advanced carotid atherosclerosis is still largely driven by the findings of the Asymptomatic Carotid Atherosclerosis Study (ACAS),¹⁶ and the treatment of symptomatic patients by North American Symptomatic Carotid Endarterectomy Trial (NASCET),¹⁷ both of which excluded patients aged 80 and over from randomization. Even in more recent trials such as the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST), only 52 of the 2,502 (2%) study participants were aged 85+, the age group within which nearly one-third of stroke patients are forecast to have their stroke and require secondary stroke prevention interventions.¹⁸ Carotid revascularization offers a solid example of the problems with underrepresentation of the elderly, as there is clear evidence of effect modification of approaches by age,¹⁹ underscoring the importance of understanding treatment effects specifically in the oldest elderly. In addition, despite the 1993 Revitalization Act requiring broader inclusion of underrepresented groups in NIH-funded clinical trials, participation by ethnic minority populations remains low.^{20,21} In addition,

while much of the emphasis has been on the recruitment of blacks into trials,²⁰ the most rapid increases in stroke incidence is likely to be for Hispanics. To the knowledge of the authors, the Secondary Prevention of Small Subcortical Stroke Study (SPS3) is the only stroke clinical trial with explicit Hispanic recruitment goals.²² It seems clear that the two most rapidly growing groups of patients at risk for stroke, the elderly and minority patients, are strikingly underrepresented in prevention and treatment clinical trials (and other clinical studies), and we seem to be on a path where we will be incapable of providing clear evidence-based guidance for the prevention and treatment of stroke in these populations.

Ethically, in a political environment in which the limitations on the resources that can be devoted to the healthcare system are becoming clearer, the allocation of resources for the secondary prevention of stroke in the “oldest old” will clearly raise difficult issues. As the limitations on resources that can be devoted to the healthcare delivery system become more widely recognized, it seems likely that allocation of these resources to expensive secondary prevention interventions to the expected one-third of stroke victims over age 85 will engender discussions regarding the value of the investment. Life expectancy of the general population at age 85 is 6.5 years.²³ Using carotid revascularization as the example, the periprocedural primary outcome (stroke, death, or myocardial infarction) rate among symptomatic patients in CREST was 6.7% for those treated with carotid stenting and 5.4% for those treated with endarterectomy.¹⁸ The increased short-term endarterectomy-related adverse event rate was considered acceptable because of the lower expected event rate over a longer follow-up relative to allowing the high-grade carotid stenosis to remain untreated. However, given the multiple years that it might take to recoup the short-term adverse event disadvantage, the short life-expectancy of those 85 years and over, and the cost of the procedures (between \$6,000 and \$13,000, depending on stenting versus endarterectomy and whether there are associated comorbidities with the procedure),²⁴ it may be reasonable to question whether revascularization among stroke survivors over 85 is warranted? At a minimum, research on this question is urgently needed.

Clearly there are limitations to these forecasts. Again, the often cited quotes regarding forecasting are funny only because they are so true. Such quotes include:

“It is often said there are two types of forecasts... lucky or wrong!!!!” (credited to *Control* magazine, published by the Institute of Operations Management).

“Forecasting future events is often like searching for a black cat in an unlit room, that may not even be there.” (credited to Steve Davidson in *The Crystal Ball*).

“Prediction is very difficult, especially if it’s about the future.” (credited to Nils Bohr).

The likelihood that these forecasts are precisely correct is small. However, the census forecasts over the next 40 years of the population distribution of those over age 45 are all based on individuals that are already currently alive. As such, these forecasts are reliable, as they do not have to incorporate the higher degree of uncertainty of future births. Although there is substantial uncertainty regarding the future of incidence rates of stroke, these huge population shifts seem quite likely to drive the general pattern of changes in the distribution of stroke (specifically substantial increases in the elderly and minorities) in the predicted direction.

In conclusion, the future of stroke in the United States seems likely to include (1) a substantial increase in the number of stroke events, (2) an increasing proportion of stroke victims being among the “oldest old” (both 75+ and 85+ years), and (3) an increasing representation of minorities, particularly Hispanics. As we look beyond 2050, the very large number of Hispanics currently below age 45 seems likely to ensure even greater increases in

the representation of Hispanics among stroke victims. These population shifts imply logistical, scientific, and ethical challenges that we are poorly prepared to address at present. Urgent attention is needed to develop effective stroke prevention and treatment approaches to ameliorate this impending public health calamity.

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Figure 1.

U.S. Census projection of the population distribution for years 2010 and 2050 shown by race/ethnicity and age.

Figure 2.

Projection of the distribution of incident stroke events for the years 2010 and 2050, shown by race/ethnicity and age (for ages 45 and over). This projected distribution of incident stroke is the product of the shifts in the population (see Fig. 1) and estimates of stroke incidence (see Table 1).

Stroke incidence rates estimated from the Greater Cincinnati/Northern Kentucky Stroke Study (GCNKSS) and the Brain Attack in Corpus Christi Study (BASIC)

Table 1

Stroke incidence data per 1,000 people: blacks and whites (GCNKSS)					Stroke incidence data for Hispanics				
Data provided by Morgenstern					Data "projected" to similar age strata				
Age strata	White male	White female	Black male	Black female	Age strata reported	Hispanic (MA)-to-white risk ratio	Age strata for prediction	Hispanic-to-white relative risk used in prediction	Hispanic stroke incidence per 1,000 population
45-54	1.1	0.7	2.7	2.2	45-59	2.04	45-54	2.04	2.2
55-64	2.7	1.9	5.7	4.1	60-74	1.58	55-64	1.81	4.9
65-74	7.6	5.6	7.2	5.6			65-74	1.58	12.0
75-84	12.5	12.4	8.4	12.5	75+	1.12	75-84	1.12	14.0
85+	32.1	19.6	14.7	20.2			85+	1.00	32.1
									19.6

Note: Estimates for blacks and whites are provided directly from reports from the GCNKSS.⁶ Rates from Hispanics are estimated by assumptions where the Hispanic-to-white stroke incidence risk from BASIC¹³ are "projected" to similar age strata as used in the GCNKSS, and then applied to the white incidence rates from the GCNKSS.