HIGH LIGHT

# Projected costs of ischemic stroke in the United States

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**Abstract—***Background:* There are barriers to acute stroke care in minority groups as well as a higher incidence of ischemic stroke when compared with non-Hispanic whites. *Objective:* To estimate the future economic burden of stroke in non-Hispanic whites, Hispanics, and African Americans in the United States from 2005 to 2050. *Methods:* We used U.S. Census estimates of the race–ethnic group populations age 45 years and older. We obtained stroke epidemiology and service utilization data from the Northern Manhattan Stroke Study and the Brain Attack Surveillance in Corpus Christi project and other published data. We estimated costs directly from Medicare reimbursement or from studies that used Medicare reimbursement. Direct and indirect costs considered included ambulance services, initial hospitalization, rehabilitation, nursing home costs, outpatient clinic visits, drugs, informal caregiving, and potential lost earnings. *Results:* The total cost of stroke from 2005 to 2050, in 2005 dollars, is projected to be $1.52 trillion for non-Hispanic whites, $313 billion for Hispanics, and $379 billion for African Americans. The per capita cost of stroke estimates are highest in African Americans ($25,782), followed by Hispanics ($17,201), and non-Hispanic whites ($15,597). Loss of earnings is expected to be the highest cost contributor in each race–ethnic group. *Conclusions:* The economic burden of stroke in African Americans and Hispanics will be enormous over the next several decades. Further efforts to improve stroke prevention and treatment in these high stroke risk groups are necessary.

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Stroke is the third leading cause of death in the United States and the leading cause of adult disability. Not only does stroke represent an enormous public health problem, but it also represents a serious public financial burden. The lifetime cost of ischemic stroke was greater than $90,000 for an individual in 1990,[1] whereas it was estimated that for 2004, direct and indirect costs of stroke in the United States exceeded $53 billion.[2]

Ethnic disparities in stroke-related health care are a critical issue for medical and public health communities.[3] Hispanics, now the largest minority group in the United States, and African Americans (AAs), the second largest minority group, are less likely to be insured, have limited access to quality health care,[4,5] receive less adequate stroke prophylaxis,[6,7] and have a higher incidence of ischemic stroke[8,9] than non-Hispanic whites (NHWs). These minority populations have a median age 10 to 13 years younger than that of NHWs in the United States.[10] As the minority groups age, the impact of inequalities in stroke risk and stroke-related health care will result in mounting economic consequences. In this study we estimated the future economic burden of stroke in Hispanics, AAs, and NHWs in the United States, from 2005 to 2050. Comparing these high-risk, rapidly growing, minority groups with NHWs will assist public health planners in prioritizing resources and setting research agendas.

**Methods.** *Study design.* We developed a model of yearly economic burden of ischemic stroke for NHWs, Hispanics, and AAs, age 45 and older, in the United States from a societal perspective, by summing costs multiplied by resource utilization. The main outcome measure was the marginal costs, in 2005 dollars, attributable to ischemic stroke in each ethnic group, age 45 years and older, from 2005 through 2050. Per capita costs were also calculated for the three groups by dividing the total costs by the average number of people in the population over the 45 years. Epidemiologic and resource utilization data were sought from two multiethnic, population-based, stroke surveillance studies: the Northern Manhattan Stroke Study (NOMASS) and the Brain Attack Surveillance in Corpus Christi (BASIC) project. NOMASS was a population-based incidence and case-control study designed to capture all strokes within northern Manhattan, occurring in

**Editorial, see page 1328**

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residents of the following zip codes: 10032, 10033, 10034, and 10040. Hispanics comprise over half of the community and are made up of predominantly Dominicans, Puerto Ricans, and Cuban Americans. Approximately 22% of the community is NHW and 13% AA. BASIC is an ongoing population-based stroke surveillance study conducted in Nueces County, TX. Hispanics, the overwhelming majority of whom are Mexican American (MA), comprise approximately 56% of this county's population. Nueces County is made up of 38% NHWs and 4% AAs. In BASIC and NOMASS, both active and passive surveillance are used to ensure complete case capture. Detailed methods of these studies have been previously published.[8,9,11,12] NOMASS is approved by the Columbia University Institutional Review Board. BASIC is approved by the University of Michigan Institutional Review Board as well as all Nueces County Hospitals.

When epidemiologic or resource utilization data were available specific to race–ethnic groups from both BASIC and NOMASS, a weighted average was determined using data from the two sources. If the data were available from only one of these sources, this information was used exclusively. When no race–ethnic-specific information was available from either of these two sources, race–ethnic-specific national statistics were used. If no race–ethnic-specific information was available, national statistics for all race–ethnic groups were used. No cost data were ascertained from NOMASS or BASIC to avoid concerns about a regional bias. Costs were estimated directly from Medicare reimbursement, averaged across all states, or from other studies that used Medicare reimbursement. Costs in the literature were adjusted to represent current costs using the medical care component of the Consumer Price Index. All costs were estimated in 2005 dollars. Marginal costs related to stroke rather than average costs were considered.

*Epidemiologic model.* We used the following elements and sources of data to construct the epidemiologic model of yearly economic burden of ischemic stroke in the three race–ethnic groups. Assumptions made during the construction of the model are also provided. The epidemiologic model accounted for incident ischemic strokes (defined here as any new ischemic stroke: first ever or recurrent) and prevalent ischemic strokes. Intracerebral hemorrhage, subarachnoid hemorrhage, and TIAs were not considered.

*Population projections.* The 2000 U.S. Census calculates multiple series of projected population growth based on varying fertility, life expectancy, and net immigration estimates.[13] The middle series, which uses the middle estimates of these three population growth contributors, was used for the base population estimates of NHWs, Hispanics, and AAs. Undocumented Hispanics were therefore not taken into account. Yearly estimates are available for 2005 to 2010, after which every 5 year estimates are reported. Previous years' estimates were carried forward when yearly recalculations were not available, to generate a conservative estimate of population growth.

*Epidemiology of stroke by race–ethnic group.* Age-specific (45 to 64, 65 to 84, and 85 and older) and race–ethnic-specific cumulative incidence data for first-ever stroke were calculated from NOMASS and BASIC, using as the denominator the race–ethnic group living in the respective regions, identified by race–ethnicity questions administered by the U.S. Census. For Hispanics, a weighted average of the two incidences for first-ever ischemic strokes was calculated to reflect the relative proportion of Hispanics each study represents. The BASIC incidence received a higher weight as MAs represent 58.5% of U.S. Hispanics, whereas Dominicans (2.2%), Puerto Ricans (9.6%), and Cuban Americans (3.5%), represented by NOMASS, comprise a smaller proportion. Based on the U.S. Census, the remaining Hispanics are from Central America (5.1%), South America (4.0%), Spain (0.3%), and "other" (15.7%). Weighting for NHWs and AAs was based on the relative census populations attributable to the BASIC and NOMASS catchment areas. Cumulative incidence of recurrent strokes was only available from the BASIC study. Age-grouped prevalence of strokes in each race–ethnic group was determined from the National Health Interview Survey.[14]

*Cost of direct medical care in stroke.* First-ever strokes and recurrent strokes were assumed to incur the same direct costs.[15] Direct costs considered for incident strokes included ambulance services, initial hospitalization, inpatient and outpatient rehabilitation services including durable medical equipment, nursing home costs, and outpatient neurology clinic visits. Direct costs of prevalent stroke included drugs, doctor visits, and informal caregiving.

Ambulance costs. The proportions of ischemic stroke patients in each race–ethnic group arriving by ambulance were estimated from BASIC (BASIC, unpublished). Average allowable costs reimbursed by Medicare were used to estimate ambulance costs.[16]

Inpatient hospitalization. All patients were assumed to be hospitalized for any incident ischemic stroke. Costs for hospitalization were estimated from the literature.[15]

Inpatient rehabilitation. For each race–ethnic group, the proportion of stroke patients admitted for inpatient rehabilitation was calculated from the weighted average of NOMASS and BASIC stroke patients. Costs were based on maximum allowable Medicare reimbursement for rehabilitation.[16]

Nursing home. The proportion of stroke patients discharged to a nursing home was calculated from the weighted average of NOMASS and BASIC stroke patients for each race–ethnic group. Costs for nursing home care[15] and average length of stay were obtained from the literature.[1]

Drugs. Costs of antiplatelets, anticoagulants, antihypertensive, and lipid-lowering agents were considered. Costs related to diabetes medications were not included as management of diabetes is not currently dependent on stroke status. The proportions of stroke patients of each race–ethnic group discharged on aspirin, warfarin, clopidogrel, and aspirin/dipyridamole were obtained from BASIC. The marginal cost of lipid-lowering and antihypertensive agents was considered. Those with hypertension were assumed to require more aggressive control of blood pressure,[17] and those with a history of hyperlipidemia were assumed to require additional statin agents,[18] following stroke. The proportion with a history of hypertension and hyperlipidemia at the time of stroke was calculated based on the weighted average of BASIC and NOMASS stroke patients for each race–ethnic group. The current price of a statin was reduced by two-thirds in anticipation of generic availability in the near future. Drug costs were obtained from the Red Book.[19]

Outpatient clinic visits. It was assumed that all patients would have one neurologist outpatient visit following an incident stroke. One additional visit with a primary care provider per year was also assumed as a result of the stroke. Medicare reimbursement for outpatient visits was used to estimate the costs for outpatient visits.

Outpatient rehabilitation. Use of home health care for therapies and durable medical equipment devices were estimated from Medicare.[20] The costs were estimated from Medicare reimbursement.[16]

Direct nonmedical costs: Informal caregiving. The proportion of stroke patients needing informal caregiving and the hours per day required were estimated from the literature.[21] The hourly salary of a home health aide[22] was used to represent the informal caregiving costs per hour.[23]

*Indirect costs.* Indirect medical costs included potential lost earnings. Lost earnings were only considered for those younger than 65, as those 65 and older were assumed to be retired. An estimate of the proportion of those in the labor force was calculated based on the race–ethnic-specific employment rate.[16] The proportion assumed to return to work following stroke (53%) was obtained from the literature.[24] Individuals were assumed to earn the median salary for each race–ethnic group.[22]

*Costs not considered.* Loss of leisure activities or other activities not related to compensated employment were not included. The effects of lost productivity in the work force incurred by others ("friction costs") were also not taken into account in the model. Stroke in those less than 45 was also excluded, as estimates of ethnic-specific stroke incidence and prevalence in this age group have not been well studied. Excluding these costs from consideration helped generate a more conservative estimate.

*Sensitivity analysis.* To determine how sensitive cost estimates were to the choice of middle series population projections, costs were also estimated using the lowest and highest series projections provided by the census. The lowest and highest series use the low and high estimates, of fertility, life expectancy, and net immigration.[13] Age-specific contributions to the population were not available for these series. Therefore, the percentage of the total population represented by the three age groups was

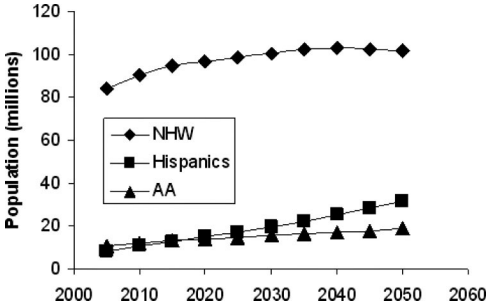


*Figure. Projection of U.S. population over age 45 from 2005 to 2050 by race–ethnic group.*

extrapolated from the middle series and used to generate the age group–specific population projections for the lowest and highest series. Costs were then calculated for these projections and compared with the costs calculated using the middle series projections.

One-way sensitivity analysis was also performed by varying the costs of the three most significant contributors to the total projected cost for each race–ethnic group. These cost values were adjusted by ±10% one at a time, and total costs were then recalculated to determine how sensitive cost estimates were to these three specific estimates. A four-way sensitivity analysis was then performed adjusting these three variables simultaneously while also using the lowest and highest series census projections to create the lowest and highest possible cost scenarios.

**Results.** *U.S. population projections.* Based on the middle series census projections, there were 70 million NHWs, Hispanics, and AAs age 45 to 64, 30 million age 65 to 84, and 5 million age 85 and older in 2005, and there will be 78 million age 45 to 64, 56 million age 65 to 84, and 17 million 85 and older in 2050. In 2005, the U.S. population was estimated to be 70% NHWs, 13% Hispanics, and 12% AAs. It is estimated that in 2050, the population will consist of 53% NHWs, 25% Hispanics, and 14% AAs. Projections of the three race–ethnic group's populations from 2005 to 2050 are found in the the figure.[13]

*Strokes by race–ethnic group.* The weighted average of the annual incidence rate of stroke in NHWs age 45 to 64 is 11 per 10,000; age 65 to 84, 60 per 10,000; and age 85 and older, 180 per 10,000. The prevalence of stroke in NHWs is estimated to be 2% for those age 45 to 64 and 9% for those age 65 and older. The weighted average of the annual incidence rate of stroke in Hispanics age 45 to 64 is 23 per 10,000; age 65 to 84, 87 per 10,000; and age 85 and older, 180 per 10,000. The prevalence of stroke in Hispanics is estimated to be 2.3% for those age 45 to 64 and 10% for those age 65 and older. The weighted average of the annual incidence rate of stroke in AAs age 45 to 64 is 33 per 10,000; age 65 to 84, 87 per 10,000; and age 85 and older, 170 per 10,000. The prevalence of stroke in AAs is estimated to be 4.8% for those age 45 to 64 and 10% for those age 65 and older.

*Costs.* The cost attributable to the use of a service or item for each incident stroke in which it is used is found in table 1. Inpatient rehabilitation was the most costly of possible services used. The yearly cost for a service or item for each prevalent stroke patient for whom it is used is also found in table 1. Yearly nursing home costs and lost earnings were the most expensive, with the distant third being the cost of informal care.

***Table 1*** *Cost per ischemic stroke for individuals using the service/item and yearly costs for individuals using the service/item*

| | Cost per stroke |
|---|---|
| Ambulance | $164 |
| Hospitalization/emergency dept. | $12,423 |
| Rehabilitation inpatient | $25,968 |
| Neurologist | $83 |
| Cost of all therapies, assistive devices, and home health | $3,218 |
| | **Cost per year** |
| Aspirin/sustained-release dipyridamole | $1,543 |
| Aspirin | $8 |
| Clopidogrel | $1,518 |
| Warfarin | $303 |
| ACE inhibitor | $384 |
| Statin | $437 |
| PCP | $53 |
| Informal care | $4,038 |
| Earnings lost | $22,880 |
| Nursing home care | $33,636 |

ACE = angiotensin-converting enzyme; PCP = primary care physician.

The total cost of stroke from 2005 to 2050 is projected to be $1.52 trillion for NHWs, $313 billion for Hispanics, and $379 billion for AAs. The per capita cost of stroke was $15,597 for NHWs, $17,201 in Hispanics, and $25,782 for AAs. In NHWs, the 45 to 64 age group accounts for approximately 45% of costs; 65 to 84, 41%; and 85 and older, 14%. In Hispanics, the 45 to 64 age group accounts for approximately 49% of costs; 65 to 84, 40%; and 85 and older, 11%. In AAs, the 45 to 64 age group accounts for approximately 67% of costs; 65 to 84, 28%; and 85 and older, 5%. An itemized account of costs contributing to the total cost of stroke by race–ethnic group from 2005 to 2050 is found in table 2. Lost earnings and informal caregiving were the highest two individual cost contributors in all race–ethnic groups, constituting approximately half of the total costs in each group. The third and fourth highest costs rankings were taken by the initial stroke hospitalization or costs of drugs.

*Sensitivity analysis.* Results of the sensitivity analyses with various adjustments to the census projections, and highest three cost contributors to each race–ethnic group are found in table 3. The total costs in NHWs ranged from $1.34 to $1.65 trillion; Hispanics, $222 to $411 billion; and AAs, $333 to $417.

**Discussion.** The indirect and direct cost of ischemic stroke in NHWs, Hispanics, and AAs and from 2005 through 2050 in the United States will likely exceed $2.2 trillion dollars, with the highest per capita contributors being AAs and Hispanics. This analysis highlights the need to examine stroke care in AAs and Hispanics further and to strengthen efforts to improve stroke prevention and acute stroke therapies for minorities. Because of the higher stroke incidence in AAs and Hispanics than NHWs and the anticipated national expenditure on stroke-related care for these groups, a stronger focus should be

***Table 2*** *Itemized cost of ischemic stroke age 45 and older for 2005 to 2050 for non-Hispanic whites, African Americans, and Hispanics*

| | Cost, $ | Percentage |
|---|---|---|
| Non-Hispanic whites | | |
| Lost earnings | 502,324,798,950 | 33 |
| Informal care | 295,386,265,848 | 19 |
| Initial hospitalization | 235,633,806,484 | 16 |
| Drugs | 229,191,507,547 | 15 |
| Inpatient and outpatient rehabilitation | 129,452,284,918 | 9 |
| Nursing home | 112,826,595,562 | 7 |
| Primary care physician | 11,832,196,761 | 1 |
| Neurologist | 1,564,434,260 | 0 |
| Total | 1,518,211,890,331 | 100 |
| African Americans | | |
| Lost earnings | 164,384,898,047 | 43 |
| Informal care | 61,295,597,330 | 16 |
| Drugs | 48,461,336,386 | 13 |
| Initial hospitalization | 47,589,455,463 | 13 |
| Inpatient and outpatient rehabilitation | 29,474,119,745 | 8 |
| Nursing home | 24,738,847,455 | 7 |
| Primary care physician | 2,455,298,882 | 1 |
| Neurologist | 315,867,637 | 0 |
| Total | 378,715,420,946 | 100 |
| Hispanic | | |
| Lost earnings | 93,488,894,235 | 30 |
| Informal care | 59,974,514,470 | 19 |
| Initial hospitalization | 55,060,188,484 | 18 |
| Drugs | 53,762,860,816 | 17 |
| Inpatient and outpatient rehabilitation | 34,136,436,848 | 11 |
| Nursing home | 13,856,652,834 | 4 |
| Primary care physician | 2,402,380,672 | 1 |
| Neurologist | 365,832,661 | 0 |
| Total | 313,047,761,022 | 100 |

placed on stroke prevention efforts and acute treatments in these minority groups.

The single largest contributor to overall costs in all race–ethnic groups was not from a direct cost, but rather was from an indirect cost, lost earnings. Because AAs and Hispanics have their strokes earlier than NHWs, the impact of lost earnings is greater than in NHWs per capita, although this is somewhat offset by the greater earnings of NHWs. It can be anticipated that as the Hispanic community becomes less of an immigrant population,[13] the average earnings of Hispanic Americans will likely rise, as will their employment rate, and thus over the next 50 years, the contribution of lost earnings is likely to increase. Similarly, as salaries in AAs continue to increase,[25] lost earnings will contribute a greater amount to the cost of stroke in the upcoming years.

***Table 3*** *Sensitivity analysis results*

| | Non-Hispanic whites | Hispanic | African Americans |
|---|---|---|---|
| Lowest series census | 1,440 | 238 | 361 |
| Highest series census | 1,540 | 385 | 389 |
| One-way sensitivity analysis range | 1,470–1,570 | 304–322 | 362–395 |
| Lowest cost case scenario | 1,340 | 222 | 333 |
| Highest cost case scenario | 1,650 | 411 | 417 |

Values are dollar figures reported in billions.

Interestingly, the younger age group consisting of the 45 to 64 year olds accounts for approximately half the total costs in this model, whereas the oldest age group, those 85 and older, accounts for approximately 10% of the costs. Although the risk of stroke is much higher in the oldest age group, the total population of the youngest age group is on average 10 times larger in size than that of the oldest age group. Furthermore, costs for the youngest age group include lost earnings, whereas this is not a contributor to the costs in the oldest age group, helping to explain this age-related cost differential. Interventions to reduce the cost of stroke must therefore not solely be targeted toward the elderly. The importance of targeting this younger population for stroke prevention strategies is underscored by the recognition that the higher risk of stroke in AAs and Hispanics compared with NHWs is greatest in this youngest age group.[8,9,26]

The cost of informal caregiving, the second largest contributor to overall costs in each race–ethnic group, is recognized to be an important factor in the cost of stroke.[21] It is even more important in the Hispanic community, as informal caregiving is more common in Hispanics than in NHWs or AAs.[27] It is likely that cultural values influence the degree of informal caregiving provided and the reliance on formal care, in addition to the degree of disability and access to outside support.[28] Informal caregiving costs are estimated to be substantial, approximately 4 times that of nursing home costs for Hispanics and approximately 2.5 times that of nursing home costs in the other race–ethnic groups in the current analysis. Nonetheless, the higher use of family caregivers in the Hispanic community and lower use of nursing homes serve to lessen overall stroke-related costs in this race–ethnic group.

The reason for the increased stroke incidence in minorities compared with NHWs is not clear and requires further study. There are differences in the prevalence of stroke risk factors by race–ethnicity. For instance, AAs have a higher prevalence of hypertension, obesity, and smoking than NHWs.[14,29] Hispanics have a higher prevalence of diabetes, obesity, inactivity, and perhaps hypertension, whereas NHWs have a higher prevalence of coronary artery disease and atrial fibrillation.[5,14,29,30] Furthermore, ethnic differences in the quality of treatment for these risk factors may contribute to the ethnic difference in stroke incidence. AAs and Hispanics are less aggressively and less successfully treated for their hypertension,[7,31] an important stroke risk factor.[29] The reason for less

aggressive risk factor modification in minorities is not apparent. Economic barriers such as the lower insurance, income, and educational status of AAs and Hispanics may be contributory,[32] but do not fully explain the disparity, at least in Hispanics.[33] Genetic factors and other social contributions, such as race–ethnic discrimination and poor neighborhood environments, are also possible explanations for the ethnic difference in stroke risk.

Although some stroke prevention modalities and treatments are cost-effective, such as carotid endarterectomy for symptomatic carotid disease,[34,35] there are some therapies that are actually cost saving. Warfarin treatment for primary prophylaxis for atrial fibrillation,[36] recombinant tissue plasminogen activator (rt-PA) administration for acute ischemic stroke,[37] smoking cessation interventions,[38] and pharmacotherapies for hypertension[39] are all cost-saving interventions. Inequalities in health care for minorities and barriers to receiving quality care need to be recognized and addressed so that all minorities can receive the full benefit of these stroke-prevention therapies. Furthermore, addressing the existing disparities in stroke prophylaxis for AAs and Hispanics would also result in lower stroke-related health care costs in these groups.

This study has limitations. As with all cost-related analyses, this study is limited by the accuracy of the cost estimates. Medicare reimbursement was used as a proxy for costs given the societal perspective, and sensitivity analyses were performed on the largest overall cost contributors in an attempt to compensate for possible inaccuracies in population and cost estimates. Future changes in stroke-related care, such as advances in therapeutics, cannot be accurately anticipated and therefore were not included in this analysis.[23] Future changes in reimbursement for stroke-related treatments and diagnostic testing were also not taken into account. For instance, the recent increase in reimbursement from Medicare for stroke hospitalizations involving rt-PA treatment was not included, contributing to the conservatism of the current study's estimates. We did not take into account the possible differences in health care costs associated with the exact distribution of race–ethnic groups in the United States with respect to urban and rural clustering or distribution by state. Last, BASIC and NOMASS have relatively small AA populations, which could have affected the precision of the estimates. One of the study's strengths is the use of data derived from a variety of Hispanic subgroups, given the known variation in healthcare resource use among Hispanics of different ancestry.[40] However, other ways in which country of origin may influence costs may exist.

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