CLINICAL RESEARCH STUDY

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Trends in Stroke Rates, Risk, and Outcomes in the United States, 1988 to 2008

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ABSTRACT

BACKGROUND: Stroke is a major cause of morbidity and mortality. We describe trends in the incidence, outcomes, and risk factors for stroke in the US Medicare population from 1988 to 2008.

METHODS: We analyzed data from a 20% sample of hospitalized Medicare beneficiaries with a principal discharge diagnosis of ischemic (n = 918,124) or hemorrhagic stroke (n = 133,218). Stroke risk factors were determined from the National Health and Nutrition Examination Survey (years 1988-1994, 2001-2008) and medication uptake from the Medicare Current Beneficiary Survey (years 1992-2008). Primary outcomes were stroke incidence and 30-day mortality after stroke hospitalization.

RESULTS: Ischemic stroke incidence decreased from 927 per 100,000 in 1988 to 545 per 100,000 in 2008, and hemorrhagic stroke decreased from 112 per 100,000 to 94 per 100,000. Risk-adjusted 30-day mortality decreased from 15.9% in 1988 to 12.7% in 2008 for ischemic stroke and from 44.7% to 39.3% for hemorrhagic stroke. Although observed stroke rates decreased, the Framingham stroke model actually predicted increased stroke risk (mean stroke score 8.3% in 1988-1994, 8.8% in 2005-2008). Statin use in the general population increased (4.0% in 1992, 41.4% in 2008), as did antihypertensive use (53.0% in 1992, 73.5% in 2008).

CONCLUSIONS: Incident strokes in the Medicare population aged ≥65 years decreased by approximately 40% over the last 2 decades, a decline greater than expected on the basis of the population's stroke risk factors. Case fatality from stroke also declined. Although causality cannot be proven, declining stroke rates paralleled increased use of statins and antihypertensive medications.

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KEYWORDS: Antihypertensive medications; Hemorrhagic stroke; Ischemic stroke; Mortality; Outcomes; Risk; Statins; Stroke; Trends

The burden of stroke in the United States is enormous. With approximately 795,000 strokes occurring each year, stroke is the fourth leading cause of death in the United States and a major source of morbidity and costs of care.[1,2] With the aging population, the absolute number of strokes in the United States is likely to increase. However, stroke is a preventable disease. Several prevention strategies have been shown to be efficacious in clinical trial settings, in particular, modification of stroke risk factors such as hypertension and hyperlipidemia.[1,3,4]

Shedding light on trends in the burden of stroke among Medicare beneficiaries may provide important information

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for policy purposes, including describing the past and current scope of the condition, assessing the potential effect of stroke-prevention interventions on a national level, and identifying areas where resources can be targeted more specifically and effectively. The primary objective of this analysis was to examine 2 decade-long trends from 1988 to 2008 in the incidence of, and subsequent short-term mortality from, stroke among individuals aged ≥65 years in the United States. We then assessed factors that could explain changes in the incidence of ischemic stroke, the highest burden subtype among elderly persons in the United States. We focused on trends in clinical risk factors for stroke and trends in the uptake of medications that attenuate stroke risk. Rates and outcomes of stroke were determined separately for men and women because of increasing evidence that there are sex-related differences in stroke incidence, risk factors, treatment, and outcomes.

CLINICAL SIGNIFICANCE

- The rate of strokes in the United States has decreased by approximately 40% from 1988 to 2008.
- Thirty-day mortality decreased over time for both ischemic and hemorrhagic strokes.
- The decline in stroke rates paralleled increasing use of antihypertensive and statin medications and might explain the reduction in stroke rates. If true, this illustrates how medical interventions have resulted in significant improvements in health on a population level.

METHODS

Data Sources, Stroke Incidence, and Mortality

We used a 20% sample of Medicare Provider Analysis and Review data to identify fee-for-service Medicare beneficiaries aged ≥65 years hospitalized for stroke between 1988 and 2008. Stroke hospitalizations were identified as principal discharge diagnoses of *International Classification of Diseases, Ninth Revision, Clinical Modification* codes of 434.x and 436.x for ischemic stroke and 430.x and 431.x for hemorrhagic stroke. Our study addressed only the first hospitalization for stroke for each individual during the time period, which was considered the index event. Although these methods assume that the stroke event was incident, we lacked information about potential stroke events that may have occurred at ages less than 65 years. We also searched for principal discharge diagnosis of transient ischemic attack (*International Classification of Diseases, Ninth Revision, Clinical Modification* code 435.x) because advances in imaging techniques may have resulted in increasing numbers of transient ischemic attacks being coded as acute ischemic strokes over time.

Medicare denominator files were used to ascertain beneficiaries' date of birth, sex, race (categorized as black, white, or other), enrollment status, region of residence (Midwest, Northeast, South, or West), and vital status (including date of death). We excluded patients residing outside the United States (n = 11,668, 1%) and patients enrolled in a Medicare health maintenance organization during the study period (n = 146,493, 14%), because Medicare Provider Analysis and Review data may not capture complete health care claims data for these individuals.

Information on clinical comorbidities was obtained using a 2-year look-back window from the index admission date, excluding diagnoses obtained solely from the index admission. The comorbidities included in the Klabunde adaptation of the Charlson comorbidity index were used for risk adjustment.[5,6]

Risk Factors and Preventive Medications

To examine possible explanations for reductions in stroke incidence, we calculated the predicted risk of stroke at 3 different time intervals using the Framingham stroke risk index, a validated instrument developed in the Framingham Heart Study cohort.[7] We obtained data on the prevalence and physiologic level of stroke risk factors among patients from the Third National Health and Nutrition Examination Survey (NHANES III) aged 65 years or older with Medicare coverage using surveys conducted from 1988 to 1994, as well as from the continuous NHANES survey data from 2001 to 2008. The NHANES is a nationally representative survey of the civilian, noninstitutionalized population, which collects detailed data on medical conditions through direct patient interview and physiologic measurements through a mobile examination component.[8] The prevalence of specific risk factors for stroke included self-reported coronary heart disease, congestive heart failure, diabetes, vascular disease, and hyperlipidemia. In addition, we obtained data on measured blood pressure, body mass index, total cholesterol, low-density lipoprotein cholesterol levels, and self-reported smoking status.

A number of medications have been shown to prevent strokes and to reduce the severity of strokes that do occur, including statins, antihypertensive agents, and antiplatelet medications.[1,9] We obtained rates of use of these medications among the Medicare population aged ≥65 years using the 1992-2008 Medicare Current Beneficiary Survey (MCBS). The MCBS is conducted on a representative sample of Medicare beneficiaries drawn from Medicare enrollment databases.[10] Community-dwelling adults provide self-reported information on medication use, which is complemented with benefit statements, pharmacy receipts, and medication containers provided to the interviewers 3 times yearly, as well as Medicare Part D prescription databases for 2006-2008. We searched for use of antihypertensive medications (including angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, beta-blockers, calcium channel blockers, diuretics, and other antihypertensive agents), statins, and non-aspirin antiplatelet agents

(clopidogrel and ticlopidine). Use of aspirin, because it is available without prescription, was not completely captured by the MCBS and was not included in the analysis.

Outcome Measures

Primary outcomes included stroke incidence and 30-day mortality, stratified by stroke subtype (ischemic vs hemorrhagic). Secondary outcomes included predicted stroke risk applying the Framingham risk equation to NHANES risk factors and rates of medication use from MCBS.

Data Analysis

Annual rates of hospitalization for first stroke were calculated for ischemic and hemorrhagic strokes among fee-for-service Medicare beneficiaries aged ≥65 years and reported as number of events per 100,000 beneficiaries. Rates were standardized to the age and sex distribution of the year 2000 population, and trends in the risk of stroke as a function of year were assessed using logistic regression, controlling for age. Changes in the demographic and clinical characteristics of stroke patients from 1988 to 2008 were examined separately for ischemic and hemorrhagic strokes. Analysis of variance was used for comparison of continuous variables and chi-square tests for categoric variables.

Sex-specific mortality rates were ascertained at 30 days after the index stroke admission and are reported separately for ischemic and hemorrhagic strokes. Risk adjusted 30-day mortality rates were calculated using logistic regression, controlling for age, sex (except for sex-stratified analyses), race, region, and medical comorbidities.

We calculated a mean Framingham stroke risk score for NHANES respondents aged ≥65 years with Medicare coverage at 3 time intervals: 1988-1994, 2001-2004, and 2005-2008. The Framingham stroke risk score incorporates specific clinical risk factors (age, systolic blood pressure, antihypertensive treatment, diabetes mellitus, smoking status, cardiovascular disease, atrial fibrillation, and left ventricular hypertrophy) to calculate a 10-year risk of stroke.[7] Electrocardiographic data on left ventricular hypertrophy were available only for NHANES participants in years 1988-1994, so for subsequent years, left ventricular hypertrophy prevalence was estimated using data from the medical literature.[11] Likewise, atrial fibrillation prevalence was obtained from a population-based study reporting atrial fibrillation rates for the years 1992 to 2002.[12] The prevalence of atrial fibrillation for earlier and later years was imputed assuming a linear trend, and we also ran the analysis assuming no change in atrial fibrillation rates. The 10-year Framingham stroke risk score was calculated for each individual in the NHANES, and risks were then averaged over each time interval and reported as mean and standard deviation for each of the 3 time periods.

Finally, we tested for changes in the self-reported use of specific classes of medications used to prevent stroke using data from the MCBS. Rates were calculated as the proportion of MCBS participants reporting use of specific medications divided by the total number of MCBS participants in that given year. Linear regression was used to test for changes in the rate of use by year.

Analyses were performed using the SAS 9.2 statistical package (SAS Institute Inc, Cary, NC). Risk factor and medication trend analyses took into account the complex survey sample design of both the NHANES and MCBS surveys. Significance was set at $P < .05$ using 2-sided tests for all analyses. This study was approved by the institutional review board of the University of California, San Francisco.

RESULTS

Trends in Stroke Incidence

We identified 1,051,342 incident strokes from 1988 to 2008 (representing 20% of Medicare claims), of which 918,124 (87.3%) were ischemic and 133,218 (12.7%) were hemorrhagic strokes. Patients presenting with stroke frequently had concomitant risk factors, the most prevalent being hypertension, diabetes, and hyperlipidemia (**Tables 1** and **2**). A prior diagnosis of transient ischemic attack at age ≥65 years was observed among 64,749 patients (7.1%) with ischemic stroke and 6261 patients (4.7%) with hemorrhagic stroke.

The incidence of first stroke decreased significantly over time, from an age-adjusted rate of 1039 per 100,000 (95% confidence interval [CI], 1032-1045) in 1988 to 639 per 100,000 (95% CI, 634-644) in 2008. The decline was largely due to a marked reduction in the rate of ischemic stroke, which decreased overall from 927 per 100,000 (95% CI, 923-931) in 1988 to 545 per 100,000 (95% CI, 542-548) in 2008 ($P < .001$). In men, the rates were 955 per 100,000 (95% CI, 948-962) and 505 per 100,000 (95% CI, 500-509); in women, the rates were 908 per 100,000 (95% CI, 902-913) and 572 per 100,000 (95% CI, 568-577) (P values $< .001$) (**Figure 1**).

Rates of hemorrhagic stroke did not show as great a decline as ischemic stroke, decreasing from 112 per 100,000 (95% CI, 110-113) in 1988 to 94 per 100,000 (95% CI, 93-95) in 2008 ($P < .001$) (112 per 100,000 [95% CI, 110-115] and 88 per 100,000 [95% CI, 86-90] in men and 111 per 100,000 [95% CI, 109-113] and 98 per 100,000 [95% CI, 97-100] in women [$P < .001$ for both, **Figure 1**]). Transient ischemic attack incidence decreased significantly over the time period, from an age-adjusted rate of 417 per 100,000 (95% CI, 414-420) to 266 per 100,000 (95% CI, 264-268) (412 per 100,000 [95% CI, 407-416] to 234 per 100,000 [95% CI, 231-237] for men, and 421 per 100,000 [95% CI, 417-424] to 288 per 100,000 [95% CI, 285-291] for women [$P < .001$ for both]).

Trends in Stroke Mortality

Crude 30-day mortality from ischemic stroke decreased from 16.2% in 1988 to 15.2% in 2008 ($P < .001$), as did risk-adjusted mortality: 15.9% in 1988 to 12.7% in 2008

Table 1 Baseline Characteristics of Medicare Patients with Ischemic Stroke Stratified by Sex* (1998-2008)

	No. (%) of Men†			No. (%) of Women†		
	1988-1994 (n = 139,200)	1995-2001 (n = 124,905)	2002-2008 (n = 101,960)	1988-1994 (n = 202,302)	1995-2001 (n = 194,732)	2002-2008 (n = 155,025)
Age, y						
65-69	23,515 (16.9)	19,237 (15.4)	15,324 (15.0)	21,262 (10.5)	18,448 (9.5)	13,940 (9.0)
70-74	30,439 (21.9)	25,831 (20.7)	19,212 (18.8)	31,438 (15.5)	28,518 (14.6)	20,425 (13.2)
75-79	32,503 (23.4)	28,779 (23.0)	22,163 (21.7)	40,936 (20.2)	38,479 (19.8)	28,158 (18.2)
80-84	27,627 (19.9)	25,660 (20.5)	21,704 (21.3)	44,819 (22.2)	43,069 (22.1)	34,843 (22.5)
≥85	25,116 (18.0)	25,398 (20.3)	23,557 (23.1)	63,847 (31.6)	66,218 (34.0)	57,659 (37.2)
Race						
White	118,762 (85.3)	106,874 (85.6)	85,775 (84.1)	172,756 (85.4)	164,980 (84.7)	130,135 (83.9)
Black	13,998 (10.1)	13,232 (10.6)	11,431 (11.2)	22,682 (11.2)	22,860 (11.7)	18,257 (11.8)
Other	6440 (4.6)	4799 (3.8)	4754 (4.7)	6864 (3.4)	6892 (3.5)	6633 (4.3)
Region						
Midwest	36,631 (26.3)	33,770 (27.0)	26,682 (26.2)	52,457 (25.9)	51,359 (26.4)	39,910 (25.7)
Northeast	30,388 (21.8)	24,598 (19.7)	18,745 (18.4)	44,963 (22.2)	38,841 (20.0)	29,602 (19.1)
South	51,827 (37.2)	50,021 (40.1)	41,936 (41.1)	76,446 (37.8)	80,239 (41.2)	64,849 (41.8)
West	20,354 (14.6)	16,516 (13.2)	14,597 (14.3)	28,436 (14.1)	24,293 (12.5)	20,664 (13.3)
Length of stay, median (25th-75th percentile), d	7 (4-12)	5 (3-9)	4 (3-7)	8 (5-13)	5 (3-9)	5 (3-7)
Discharge type						
Home, self-care	58,473 (42.0)	45,848 (36.7)	32,471 (31.9)	69,584 (34.4)	56,633 (29.1)	36,450 (23.5)
Skilled nursing facility	20,221 (14.5)	25,029 (20.0)	20,001 (19.6)	41,385 (20.5)	51,970 (26.7)	41,501 (26.8)
Other type of inpatient facility	29,096 (20.9)	30,785 (24.7)	30,147 (29.6)	42,704 (21.1)	47,974 (24.6)	45,806 (29.6)
Dead	15,766 (11.3)	10,392 (8.3)	6,489 (6.7)	22,416 (11.1)	16,100 (8.3)	10,324 (6.7)
Other	15,644 (11.2)	12,851 (10.3)	12,852 (12.6)	26,213 (13.0)	22,055 (11.3)	20,944 (13.5)
Comorbid Conditions						
Myocardial infarction	8902 (6.4)	11,924 (9.55)	10,341 (10.14)	9841 (4.86)	14,298 (7.34)	12,414 (8.01)
Congestive heart failure	17,711 (12.72)	20,503 (16.41)	18,147 (17.8)	31,189 (15.42)	37,717 (19.37)	32,219 (20.78)
Hypertension	26,107 (18.76)	43,007 (34.43)	48,069 (47.14)	50,187 (24.81)	82,922 (42.58)	85,843 (55.37)
Diabetes	18,133 (13.03)	23,852 (19.1)	24,055 (23.59)	29,710 (14.69)	37,735 (19.38)	34,789 (22.44)
Atrial fibrillation	14,638 (10.52)	18,907 (15.14)	18,132 (17.78)	25,418 (12.56)	33,042 (16.97)	30,882 (19.92)
Vascular disease	6843 (4.92)	8714 (6.98)	8272 (8.11)	6786 (3.35)	9728 (5.00)	9171 (5.92)
Hyperlipidemia	1924 (1.38)	9464 (7.58)	23,814 (23.36)	3959 (1.96)	15,951 (8.19)	35,247 (22.74)

*Characteristics are number (percentages) unless otherwise indicated. Data are from a 20% sample of Fee-For-Service Medicare enrollees aged ≥65 years. Comorbid conditions are defined using the Klabunde adaptation of the Charlson score. Partial list of comorbid conditions presented. *P* value for trend < .001.

†Percentages may not sum to 100 because of rounding.

Table 2 Baseline Characteristics of Medicare Patients with a Hemorrhagic Stroke Stratified by Sex* (1998-2008)

	No. (%) of Men†			No. (%) of Women†		
	1988-1994 (n = 17,734)	1995-2001 (n = 18,491)	2002-2008 (n = 17,423)	1988-1994 (n = 26,399)	1995-2001 (n = 28,042)	2002-2008 (n = 25,129)
Age, y						
65-69	3645 (20.6)	3134 (17.0)	2678 (15.4)	3848 (14.6)	3274 (11.7)	2640 (10.5)
70-74	4179 (23.6)	4129 (22.3)	3521 (20.2)	4944 (18.7)	4631 (16.5)	3757 (15.0)
75-79	4190 (23.6)	4399 (23.8)	3993 (22.9)	5588 (21.2)	5920 (21.1)	5017 (20.0)
80-84	3218 (18.2)	3634 (19.7)	3682 (21.1)	5554 (21.0)	6142 (21.9)	5745 (22.9)
≥85	2502 (14.1)	3195 (17.3)	3549 (20.4)	6465 (24.5)	8075 (28.8)	7970 (31.7)
Race						
White	15,081 (85.0)	16,008 (86.6)	14,872 (85.4)	22,776 (86.3)	24,116 (86.0)	21,233 (84.5)
Black	1595 (9.0)	1545 (8.4)	1512 (8.7)	2504 (9.5)	2612 (9.3)	2386 (9.5)
Other	1058 (6.0)	938 (5.1)	1039 (6.0)	1119 (4.2)	1314 (4.7)	1510 (6.0)
Region						
Midwest	4483 (25.3)	4848 (26.2)	4318 (24.8)	6752 (25.6)	7351 (26.2)	6405 (25.5)
Northeast	3965 (22.4)	3772 (20.4)	3510 (20.2)	5985 (22.7)	5911 (21.1)	4993 (19.9)
South	6450 (36.4)	7099 (38.4)	6745 (38.7)	9680 (36.7)	10,799 (38.5)	9836 (39.1)
West	2836 (16.0)	2772 (15.0)	2850 (16.4)	3982 (15.1)	3981 (14.2)	3895 (15.5)
Length of stay, median (25th-75th percentile), d	7.5 (3-15)	5 (2-11)	5 (2-10)	8 (3-15)	5 (2-11)	5 (2-9)
Discharge type						
Home, self-care	3934 (22.2)	3359 (18.2)	2679 (15.4)	4915 (18.6)	3920 (14.0)	2903 (11.5)
Skilled nursing facility	2275 (12.8)	3269 (17.7)	2838 (16.3)	4646 (17.6)	6291 (22.4)	5262 (20.9)
Other type of inpatient facility	4031 (22.7)	4741 (25.6)	5354 (30.7)	5374 (20.4)	6689 (23.9)	7464 (29.7)
Death	6516 (36.7)	6219 (33.6)	5510 (31.6)	9893 (37.5)	9645 (34.4)	7859 (31.3)
Other	978 (5.5)	903 (4.9)	1042 (6.0)	1571 (6.0)	1497 (5.3)	1641 (6.5)
Comorbid Conditions						
Myocardial infarction	645 (3.64)	1119 (6.05)	1335 (7.66)	608 (2.3)	1144 (4.08)	1389 (5.53)
Congestive heart failure	1164 (6.56)	1901 (10.28)	2405 (13.8)	1967 (7.45)	3200 (11.41)	3619 (14.4)
Hypertension	2799 (15.78)	5293 (28.62)	7702 (44.21)	4865 (18.43)	9195 (32.79)	12,111 (48.2)
Diabetes	1263 (7.12)	2199 (11.89)	3355 (19.26)	1899 (7.19)	2856 (10.18)	3929 (15.64)
Atrial fibrillation	1174 (6.62)	2318 (12.54)	3334 (19.14)	1644 (6.23)	3167 (11.29)	4015 (15.98)
Vascular disease	607 (3.42)	1011 (5.47)	1242 (7.13)	529 (2)	933 (3.33)	1101 (4.38)
Hyperlipidemia	196 (1.11)	1292 (6.99)	4111 (23.6)	384 (1.45)	1842 (6.57)	5226 (20.8)

*Characteristics are number (percentages) unless otherwise indicated. Data are from a 20% sample of Fee-For-Service Medicare enrollees aged ≥65 years. Comorbid conditions are defined using the Klabunde adaptation of the Charlson score. Partial list of comorbid conditions are presented here. *P* value for trend <.001.

†Percentages may not sum to 100 because of rounding.

($P < .001$). The 30-day mortality from ischemic stroke decreased from 16.3% to 11.2% in men and from 15.6% to 13.6% in women ($P < .001$ for both, Figure 2).

Thirty-day mortality from hemorrhagic stroke also decreased over time, albeit less so than ischemic stroke: Crude mortality rates decreased from 43.4% in 1988 to 42.1% in 2008 and risk-adjusted from 44.7% to 39.3% ($P < .001$ for both, Figure 2). The 30-day mortality from hemorrhagic stroke decreased from 45.2% to 38.8% among men and from 44.4% to 39.6% among women ($P < .001$ for both, Figure 2).

Trends in Risk Factors and Predicted Incidence of Stroke

Table 3 presents the prevalence of individual stroke risk factors and the corresponding calculated Framingham stroke risk scores for the US population aged ≥65 years with Medicare coverage for 3 time periods. Although the prevalence of diabetes mellitus increased over time, other risk factors, such as cigarette smoking, measured systolic blood pressure, and total cholesterol values, decreased. By using risk factor prevalence from NHANES to calculate Framingham stroke risk scores, the mean 10-year predicted stroke risk in the population aged ≥65 years increased from 8.3% in 1988-1994 to 8.8% in 2005-2008 ($P = .02$). For men, predicted stroke risk decreased slightly from a mean Framingham score of 10.7% in 1988-1994 to 10.2% in 2005-2008 ($P = .06$); for women, predicted stroke risk increased significantly from 6.5% in 1988-1994 to 7.7% in 2005-2008 ($P < .001$). The mean predicted Framingham stroke risk when the prevalence of atrial fibrillation was assumed to be unchanged over the time period was 8.3% in 1988-1994 and 8.5% in 2005-2008 ($P = .38$).

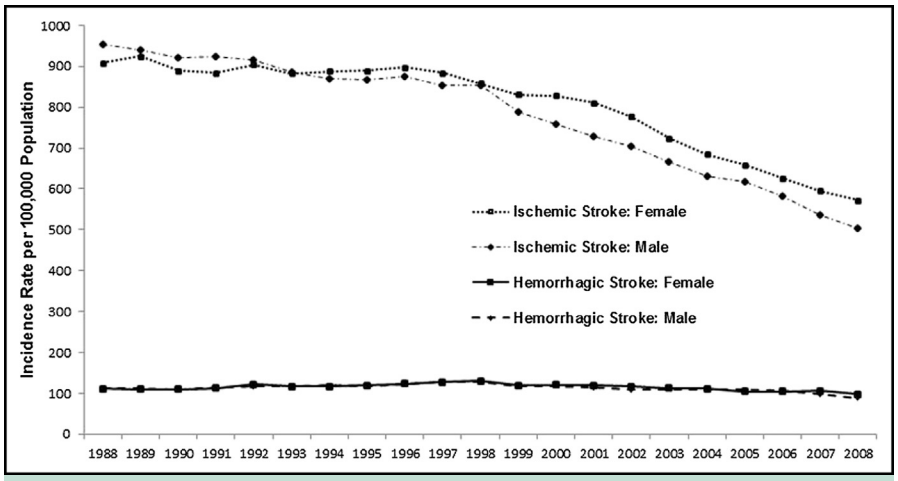

Figure 1 Age-adjusted incidence of ischemic and hemorrhagic stroke in the US Medicare population from 1988 to 2008.

Trends in Medication Use

Figure 3 shows trends in the use of antihypertensives, statins, and non-aspirin antiplatelet agents by Medicare beneficiaries aged 65 years or more. Antihypertensive medication use increased significantly from 1992 to 2008, as did statin use ($P < .001$ for both), which showed a marked increase particularly after 1996. We also observed increased prescription antiplatelet medication use over the time period, but the overall prevalence of antiplatelet use in the population was low.

DISCUSSION

The rate of first stroke among patients aged ≥65 years decreased by approximately 40% over the last 2 decades in the US Medicare population, a decline driven primarily by marked reductions in the incidence of ischemic stroke. Hemorrhagic stroke rates showed a smaller decline, primarily among men. Short-term mortality from both ischemic and hemorrhagic strokes also declined over time, although hemorrhagic strokes continue to be associated with poor outcomes. The large decline in stroke rates was not matched by concomitant reductions in stroke risk factors that were part of the Framingham stroke risk score, but did parallel a substantial increase in the use of antihypertensive medications and statins in the general Medicare population.

Our study confirms earlier reports of declining stroke rates and was able to compare how the prevalence of stroke risk factors tracked with actual observed rates in stroke.[13-17]

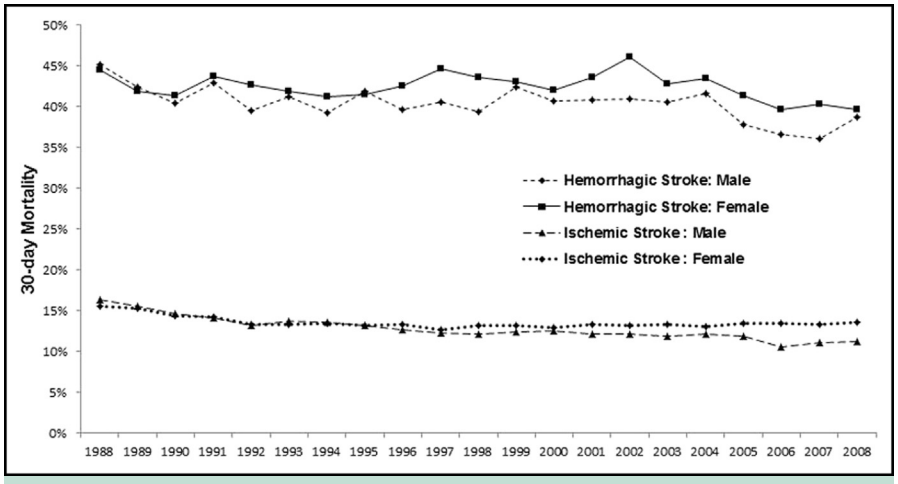

Figure 2 Risk-adjusted 30-day mortality rates after hospitalization for ischemic or hemorrhagic stroke from 1988 to 2008 in a 20% sample of Medicare patients, adjusted for age, region, race, acute/prior myocardial infarction, congestive heart failure, vascular disease, pulmonary disease, dementia, paralysis, diabetes, renal disease, liver disease, ulcer disease, rheumatologic disease, and cancer.

Table 3 Prevalence of Stroke Risk Factors in National Health and Nutrition Examination Survey Subjects Aged ≥65 Years and Medicare Enrolled, Years 1988-1994, 2001-2004, and 2005-2008

	1988-1994		2001-2004		2005-2008	
	Men (n = 2301)	Women (n = 2649)	Men (n = 1148)	Women (n = 1293)	Men (n = 1003)	Women (n = 1024)
Age, y (mean)	73.1	74.3	73.9	74.8	73.5	74.1
Diabetes mellitus (%)	12.2	13.3	18.7	17.1	18.3	16.2
Current smoker (%)	15.1	10.9	9.7	6.4	8.4	9.1
Cardiovascular disease	18.1	14.1	21.2	14.6	20.4	11.9
Systolic blood pressure	140	142	133	142	134	140
Total cholesterol	210	230	194	217	183	206
High-density lipoprotein cholesterol	46	56	48	61	50	61
Left ventricular hypertrophy[11]	4.5	1.5	4.0	1.0	4.0	1.0
Atrial fibrillation[12]	3.8	3.3	8.0	6.9	8.5	7.1
Blood pressure medication	29.1	39.6	48.0	54.3	51.2	58.6
10-y predicted Framingham stroke risk[10]						
Predicted risk of stroke	10.7%	6.5%	10.4%	7.7%	10.2%	7.7%
Standard deviation	0.07	0.05	0.07	0.06	0.06	0.06

Although some risk factors for stroke declined over time, such as reductions in rates of smoking, total cholesterol level, and systolic blood pressure, the magnitude of the observed reductions in stroke rate was greater than what might be estimated by the Framingham stroke score. It is possible that the Framingham stroke risk score does not validate well in our population. The increase in mean Framingham risk score in our study was primarily driven by an increase in the rates of diagnosed diabetes mellitus and the increased prevalence of antihypertensive medication use. Because criteria for diabetes mellitus diagnosis have changed over time, as have goal blood pressure targets, the calculated stroke risk score may not accurately reflect differences in actual stroke risk. The effect of risk factor changes also may not be detectable in the short-term. The Framingham model was developed in a cohort of well-educated, middle-class individuals of predominantly European descent and may not reflect the baseline cardiovascular risk and racial/ethnic composition of the Medicare population we studied.

It also is possible that improved risk factor modification, such as more stringent blood pressure control and administration of statins, has significantly decreased the population stroke rate. Although our study design precludes us from making causal explanations, the decline in stroke rates occurred over a period of significant uptake in the use of medications that attenuate stroke risk. Antihypertensive medications reduce the risk of stroke by approximately

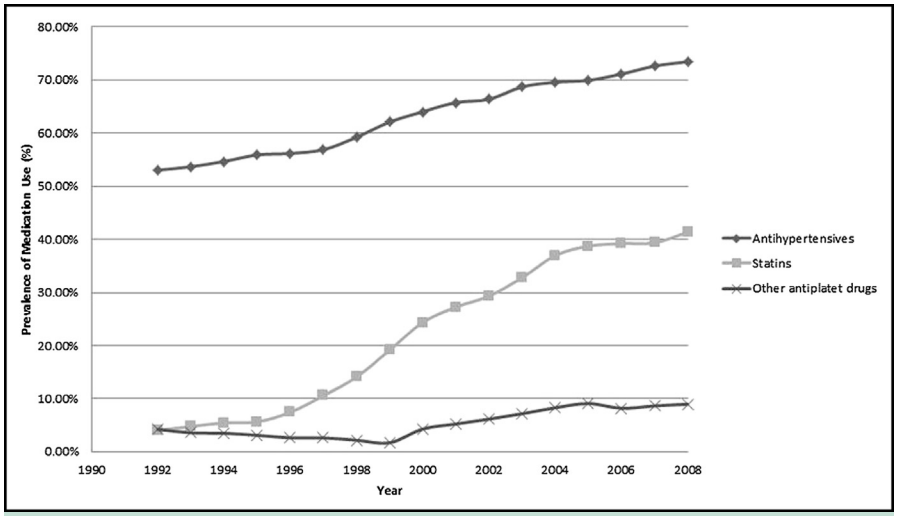

Figure 3 Prevalence of medications used to prevent stroke among 138,821 participants aged ≥65 years in the MCBS (1992-2008).

32%, and statins reduce the risk of stroke by approximately 21%.[1,3,4] Stroke rates seem to decrease most sharply after year 1998, approximately when statin use became more prevalent. Use of prescription antiplatelet agents increased over the time period, but these agents were unlikely to be a major contributing factor to the reduction in stroke rates because of the weak effects of antiplatelets on primary stroke prevention and the low prevalence of use in our study.

Short-term stroke-related mortality from stroke has decreased significantly over time. Our analysis confirms the continuing and devastating effect of hemorrhagic stroke. Our analysis was unable to assess for causal factors influencing mortality rates; relatively few interventions have been shown to reduce stroke-related mortality. Timely administration of intravenous thrombolytics is associated with more favorable outcomes from ischemic stroke, but has not been shown to have significant effects on mortality.[9] In addition, the rate of thrombolytic administration continues to be low in the United States.[18]

Study Limitations

Our report focuses on the US population aged ≥65 years and so is unable to assess trends in stroke rates and case fatality in younger individuals. In addition, although it was likely that the majority of strokes were incident events, it is possible that some subjects had stroke events at ages <65 years that could not be captured by the Medicare database. Thus, our study can only comment on stroke rates occurring at ages 65 years and older. Stroke events were identified using administrative data, which are subject to misclassification and imperfect sensitivity and specificity. However, we note that the primary objective was to describe relative rather than absolute changes in incidence and mortality over time. We were not able to determine causality between medication use and stroke rates and outcomes, and we lacked accurate assessments of nonprescription medications, in particular, aspirin. Although aspirin does not seem to have strong effects in the primary prevention of ischemic stroke, it may have small effects on reducing the risk of incident stroke in women.[1] We obtained data from several databases that had different means of data collection and ascertainment of risk factors. Unmeasured or unknown factors other than the risk factors and medications we examined in the analyses may have contributed to the observed reduction in stroke rate. In addition, we were not able to ascertain whether the medications studied were specifically used for stroke risk reduction or for the secondary prevention of stroke. Atrial fibrillation and left ventricular hypertrophy were extrapolated from national estimates, although our findings did not change when we assumed that the prevalence of atrial fibrillation was unchanged over the time period. Because the actual prevalence of atrial fibrillation seems to be increasing over time, it is unlikely that the observed declines in stroke rates were due to the decreased population prevalence of atrial fibrillation.[19]

CONCLUSIONS

The rates of incident stroke have significantly decreased over the last 20 years in the US Medicare population, as has short-term stroke mortality. Antihypertensive medications and statin use increased significantly over the time period and might explain the observed decline in stroke rates. If true, then this illustrates how medical interventions have resulted in significant improvements in health on a population level.

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