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Background and Purpose Although stroke mortality has been declining in the United States for decades, recent trends in stroke incidence based on national data have not been described. We used Medicare hospitalization data to estimate national trends in the incidence of stroke among Americans aged 70 years or older, and we provide evidence of the validity of the estimate.

Methods We defined stroke as a principal diagnosis with International Classification of Diseases, 9th Revision, Clinical Modification codes 430 to 434 or 436 to 437. We excluded many recurrent cases from the analysis by eliminating persons hospitalized for stroke during the 5 years preceding the index stroke. We calculated annual adjusted incidence rates and examined trends graphically. We investigated the effect of different exclusion periods, trends in in-hospital mortality of stroke patients, and trends in out-of-hospital stroke mortality. We examined trends in relation to sex, race, and age.

Results The estimated age- and sex-adjusted stroke incidence declined 9.5% from 1985 to 1989, then increased 3.3% to 1991. The pattern did not vary with the length of the exclusion period or when all listed diagnoses rather than principal diagnoses were used to identify stroke cases. Incidence trends resembled the overall trend for both men and women, for 5-year age groups, and for whites; the trend did not change for blacks.

Conclusions Stroke incidence declined steadily from 1985 to 1989 and then increased slightly to 1991. Several postulated potential sources of bias were investigated and found to be unlikely to account for the incidence decline, although some may have contributed to the subsequent incidence increase.

Key Words • aged • epidemiology • hospitalization • incidence

The mortality rate for stroke in the United States has been declining during the past several decades, but it is not clear whether this decline is primarily attributable to a decline in stroke incidence or in case-fatality rates. Determining the relative contribution of these two factors would help in evaluating past interventions and in deciding where to focus future prevention efforts.

Unfortunately, national data on trends in stroke incidence are lacking. Such trend data are available only from community studies such as the Mayo Clinic medical records linkage system for Rochester, Minn, and the Minnesota Heart Survey for Minneapolis-St Paul. Previous estimates of national trends in stroke incidence have relied on data from the National Hospital Discharge Survey, which does not distinguish between incident cases and recurrent cases, since multiple admissions for the same person cannot be linked.

We examined recent national trends in stroke incidence among elderly persons by using Medicare hospitalization data. Approximately 95% of Americans aged 65 years or older have Medicare hospitalization insurance/ and almost 90% of stroke deaths occur in this age group. Unduplicated counts of persons hospitalized for stroke can be obtained by linking multiple records for each person. Furthermore, Medicare enrollment files are available to generate denominators for calculating rates.

We describe a method for estimating trends in the incidence of stroke, defined here as first-ever stroke, in the Medicare population, and we provide evidence of the validity of this method. We estimate trends in stroke incidence from 1985 through 1991 for the entire Medicare population aged 70 or older and for subgroups defined by age, sex, and race.

Subjects and Methods Our approach resembles that used by Whittle and coworkers and McBean and coworkers for evaluating the accuracy of Medicare hospitalization data for estimating cancer incidence. In addition, we used other data sources for evaluating the validity of the derived incidence trends.

We obtained computerized Medicare hospitalization files for 1980 through 1991 from the Health Care Financing Administration (HCFA). The files for 1980 through 1983 contain records for a systematic 20% sample of Medicare beneficiaries, those whose health insurance claim numbers (HICs) end with the digit 0 or 5. Files for 1984 through 1991 contain records for all beneficiaries. All records contain a principal diagnosis, coded according to the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) code. Records for 1983 through 1991 also contain up to four secondary diagnoses. All records also contain beneficiaries' age, sex, race, and state and county of residence, an indicator of whether the hospitalization was paid for by a health maintenance organization (HMO), and the discharge status (alive or dead).

Modified Medicare enrollment files for 1985 through 1991, also obtained from HCFA contain the same demographic and geographic information as the hospitalization records do and indicators of HMO enrollment for each beneficiary.
We identified stroke cases by searching Medicare hospitalization files for 1980 through 1991 for the 20% of beneficiaries whose HICs ended with the digit 0 or 5. We searched for beneficiaries aged 65 years or older for whom a discharge diagnosis of stroke (ICD-9-CM rubrics 430 to 434 and 436 to 438) was recorded in any of the five diagnostic code positions (for 1983 to 1991) or as the principal diagnosis (1980 to 1982). Since HMOs frequently do not submit hospitalization records to HCFA, we excluded from analysis records of patients who received their hospital care from HMOs.

We defined index cases for persons aged 70 years or older during 1985 through 1991 as the first admission in each year for which the principal diagnosis was acute stroke, using the following ICD-9-CM codes: 430 (subarachnoid hemorrhage), 431 (intracerebral hemorrhage), 432 (other and unspecified intracranial hemorrhage), 433 (occlusion and stenosis of pre-cerebral arteries), 434 (occlusion of cerebral arteries), 436 (acute, but ill-defined, cerebrovascular disease), and 437 (other and ill-defined cerebrovascular disease). This stroke definition was used to provide comparability with national statistics for death due to cerebrovascular disease, which includes ICD-9-CM rubrics 430 to 438. We excluded from our definition ICD-9-CM codes 435 (transient cerebral ischemia) and 438 (late effects of cerebrovascular disease) because, by definition, they do not include acute stroke.

We removed recurrent strokes from our set of index cases by excluding persons who had been hospitalized and assigned a principal diagnosis of acute stroke or late effects of cerebrovascular disease (ICD-9-CM code 438) during any of the 5 years before the index year; Medicare hospitalization files for 1980 through 1986 were used to search for prior strokes. Since most persons become eligible for Medicare at age 65, our procedure required that persons were aged 70 years or older at time of the index stroke, so that 5 previous years of discharge records could be examined for prior strokes. The cases remaining after the exclusion process constituted the estimated incident (first-ever) stroke cases for each index year.

We evaluated the potential bias of our estimates, associated with the use of a 5-year exclusion period for prior strokes, by shortening and lengthening the exclusion period. Since no pre-1980 records are available, the maximum number of years of exclusion for each index year is the difference between that year and 1980. Consequently, exclusions of 0 through 5 years were performed for index cases in 1985 through 1991 for persons aged 70 years or older at time of the index stroke. Exclusions of up to 6 and 8 years were used for persons aged 75 years or older during the index year periods 1986 to 1991 and 1988 to 1991, respectively.

Because of possible secular changes in the position of the stroke code on the discharge record, we performed analyses similar to those described above but used all listed diagnoses rather than the principal diagnosis alone both to identify the index stroke and to exclude recurrent cases. As noted earlier, records from 1980 to 1982 could not be used to exclude cases based on all listed diagnoses.

We prepared Medicare denominator data sets for 1985 through 1991 by aggregating the enrollment records of Medicare beneficiaries aged 70 years or older who were not enrolled in an HMO (the proportion of beneficiaries excluded based on HMO enrollment ranged from 4.4% in 1985 to 7.0% in 1991) and for whom the last HIC digit was the same as those used to determine inclusion in the hospitalization files. These records were also aggregated by 5-year age group, sex, and race. We calculated annual incidence rates, overall and within subgroups, by dividing the number of incident cases by the number of eligible persons in the denominator file.

We performed age and sex adjustment for rates obtained on the entire population and on race-specific subgroups. We age-adjusted sex-specific groups and sex-adjusted age-specific groups. Adjustment was by the direct method, using 5-year age and/or sex groupings of the 1980 US population aged 70 years or older as the standard. Standard methods were used to compute 95% confidence intervals of the adjusted rates.

By using the discharge status indicator on the Medicare hospital discharge records, we calculated age- and sex-adjusted percentages of incident stroke patients who died during the index hospitalization.

To evaluate the possible contribution of trends in out-of-hospital stroke mortality, we examined vital statistics mortality data for 1985 through 1990, obtained from the National Center for Health Statistics. Records were extracted for persons aged 70 years or older for whom the underlying cause of death was stroke (ICD-9 codes 430 to 434 or 436 to 438), and the hospital status of the decedent at death was classified into two categories: inpatient or out-of-hospital (including persons dead on arrival or who died in the emergency department). Age- and sex-adjusted rates and percentages of deaths in each category were calculated by use of intercensal population estimates for denominators.

**Results**

The number of index stroke cases in our 20% sample was 54,199 in 1985, dropping to a low of 52,377 in 1989 and then increasing to a high of 56,712 in 1991. The age- and sex-adjusted incidence rate, based on the principal diagnosis, declined steadily from 1985 to 1989, an overall 9.5% decline during the 5-year period (Fig 1). The rate increased slightly from 1989 to 1990 and then steeply to 1991. The 1991 rate was 3.3% above that for 1989 (95% confidence interval, 2.2% to 4.6%). When ICD-9-CM code 437 (other and ill-defined cerebrovascular disease) was removed from the case definition, the 7-year incidence trend was the same (data not shown).

When exclusion periods of varying lengths (up to 5 years) were used, the pattern was similar: a decline from 1985 to 1989 and then an increase to 1991 (Fig 2). Exclusion of up to 8 years of prior strokes for beneficiaries aged 75 years and older resulted in a set of curves parallel to each other and to those in Fig 2 (data not shown). When all listed diagnoses rather than principal diagnoses were used to identify index stroke cases, the pattern was also similar to that for principal diagnosis; rates declined from 1985 to 1989 and then increased to 1991 (Fig 3). In both of these analyses (Figs 2 and 3) the curves for the various exclusion periods are parallel, and most of the recurrent cases were removed by 3 years of exclusion.
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The basic method for examining incidence trend (principal diagnosis and a 5-year exclusion period) was used to investigate trends in various subgroups of the population. The trend for overall stroke incidence (Fig 1) was the same for men and for women (Fig 4), for whites (Fig 5), and for persons in different age groups (Fig 6). The pattern differed for blacks, for whom incidence changed little during the 7-year period (Fig 5).

The proportion of stroke patients who died during their index hospitalization remained about the same from 1985 through 1988 (approximately 13.2%), then declined to 11.7% in 1991 (Table). Annual age- and sex-adjusted mortality rates for stroke occurring out-of-hospital also declined steadily from 1985 through 1990 (Table). This decline largely reflects the overall declining stroke mortality; the proportion of out-of-hospital stroke deaths remained about the same (Table).

Discussion
Our study of Medicare beneficiaries describes the only currently available method for estimating trends in first-ever stroke in a large national population.

Our data suggest that stroke incidence among Medicare beneficiaries 70 years of age or older declined 9.5% between 1985 and 1989 and then increased 3.3% from 1989 to 1991. Few published reports cover the same period or population. Using the National Hospital Discharge Survey, Modan and Wagener found little change in age-adjusted hospitalization rates for stroke among persons of all ages from 1980 to 1985, a slight decline between 1985 and 1987, and a greater decline in 1988, which was attributed to a change in the hospital sampling frame. For 1980 to 1985, the Minnesota Heart Survey found no significant change in the age-adjusted rates of hospitalization for "definite" stroke for men aged 70 to 74 years and a slight increase for women in the same age range, despite a continuous decline in mortality. For residents of Rochester, Minn, the Mayo Clinic team found an increase in stroke incidence between the 5-year periods 1975 to 1979 and 1980 to 1984. The incidence trends did not differ by sex (Fig 4) or age groups (Fig 6). Differences occurred, however, by race. For whites, the pattern reflected the overall pattern (whites accounted for 91% of incident cases for 1985 to 1991), but for blacks, incidence did not change significantly during the 7-year period (Fig 5). Since the increase in the use of diagnostic imaging was greater for blacks than whites from 1985 to 1989, increased ascertainment of milder cases during this period could partly...
explain the apparent lack of a decline in incidence for blacks.

Our study has several possible sources of bias. However, since our purpose was to elucidate trends in stroke incidence, we consider the effects of each potential bias not on annual incidence rates but on trends in incidence rates.

First, our method of estimating incidence trends could be biased because of the inclusion of recurrent cases. Although we recognize that our method has not excluded all recurrent strokes but rather only those with a hospitalized stroke in the preceding 5 years, the parallel relation of the curves in Fig 2 shows that the trend is the same regardless of the number of years of prior stroke that were excluded and thus regardless of the proportion of recurrent cases remaining among the index cases. (Prior strokes that were undetected because they occurred too long in the past, did not result in patients being hospitalized, or were miscoded could have biased the incidence trend only if the biasing factors themselves changed over time.)

Second, an apparent decline in stroke incidence could have been produced by underascertainment of cases due to an increase in the proportion of strokes that cause death before hospitalization. However, national mortality statistics, although of imperfect accuracy,16 showed little change from 1985 to 1990 in the proportion of stroke deaths occurring out-of-hospital (Table).

Third, bias could have resulted from changes in the threshold for hospital admission. Apparent incidence rates could have declined because of an increasing reluctance to admit persons with less severe strokes. This would lead to an increase in the average severity of illness among hospitalized persons and thus to an increasing case-fatality rate (unless offset by an improvement in the quality of care). However, after a slight increase from 1985 to 1986, in-hospital mortality among index cases declined steadily from 1986 to 1991 (Table). Thus, this biasing factor is unlikely to have contributed to the apparent decline in stroke incidence between 1985 and 1989 but could have contributed to the increase from 1989 to 1991.

Fourth, misclassification bias could have resulted from changes in the diagnosis of stroke or other conditions included in our case definition. For example, Medicare beneficiaries' use of computed tomography and magnetic resonance imaging of the head increased substantially during the late 1980s.15 It is difficult to see how our observed decline in stroke incidence from 1985 to 1989 could have been an artificial result of the increased use of more sensitive imaging techniques. However, the increased detection of cerebrovascular disease through these neuroimaging modalities could have contributed to the observed increase in incidence from 1989 to 1991 through the diagnosis and hospital admission of more persons with less severe strokes. The decline in in-hospital mortality of stroke patients from 1989 to 1991 (Table) supports this interpretation.

Fifth, another type of classification bias could have resulted from changes in ICD-9-CM coding practices over time. Any shifts that may have occurred in the position of the ICD code for stroke in the discharge record (first-listed versus other diagnosis) appear not to have influenced the observed incidence trends since the use of all listed diagnoses, which is insensitive to such shifts, resulted in trends (Fig 2) similar to those for the first-listed diagnosis (Fig 2). There also might have been shifts over time between various ICD-9-CM rubrics used to code stroke. We minimized the impact of such shifts by employing a broad case definition for stroke, using all cerebrovascular disease codes except those for transient ischemic attacks and for late effects of stroke. However, we could not rule out the possibility of other secular changes in ICD coding methodology.

Since the ICD-9-CM code 437 (other and ill-defined cerebrovascular disease) includes some conditions that might be diagnosed in the absence of stroke (eg, nonruptured cerebral aneurysm and hypertensive encephalopathy) as well as conditions commonly diagnosed in the presence of stroke (eg, cerebral arthritis and moyamoya disease), we repeated the primary analysis (Fig 1) after excluding this code from the case definition. There was essentially no change in the shape of the incidence trend. While there is certain to be misclassification in any investigation based on the ICD-9-CM
coding system, this reanalysis supports the robustness of our findings.

Results from an independent method of stroke surveillance would be invaluable for gaining further insight into stroke incidence trends derived from Medicare claims data. Population-based clinical studies with the capacity for reviewing individual cases, such as the Rochester, Minn, record linkage system or the Minnesota Heart Study, could potentially serve this purpose.

In conclusion, we have described a method for estimating trends in stroke incidence among Medicare beneficiaries that showed a decline from 1985 to 1989, followed by an increase to 1991. Several potential biases were investigated, and evidence against their operation was presented. However, the diverging trends for incidence and case-fatality rates during the period 1989 to 1991 suggest the possibility of a selection bias in hospital admissions. The use of this methodology in conjunction with data from national vital statistics and population-based clinical studies offers an improved opportunity to monitor national trends in stroke incidence.

References
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