Trends in Stroke Incidence and Mortality in Hawaiian Japanese Men

Abraham Kagan, MD; Jordan Popper, MD; Dwayne M. Reed, MD, PhD; Charles J. MacLean, PhD; John S. Grove, PhD

Background and Purpose Vital statistics show a sharp decline in stroke mortality since the late 1960s. It is not clear whether this has been associated with a decline in stroke incidence.

Methods Since 1966 the Honolulu Heart Program has monitored the incidence and mortality of coronary heart disease and stroke in a target population of 11,136 men of Japanese ancestry living on Oahu. Trends were analyzed from January 1, 1969, through December 31, 1988.

Results Of 7,893 men aged 45 to 68 years and free of stroke at entry examination, 530 developed first episodes of stroke in the period 1969 to 1988 (389 cases of thromboembolic stroke, 124 cases of hemorrhagic stroke, and 17 cases of stroke of unknown type). Age-adjusted annual stroke incidence declined from 5.1 per 1,000 person-years in 1969 to 1972 to 2.4 in 1985 to 1988. The incidences of thromboembolic stroke, hemorrhagic stroke, and total stroke decreased 3.5%, 4.2%, and 4.4% per year, respectively. The 1-month case-fatality rates for thromboembolic stroke decreased moderately; those for hemorrhagic stroke fell dramatically.

Conclusions These findings suggest that the decline in stroke mortality in the past two or three decades results from a decline in both incidence rates and early case-fatality rates in thromboembolic and hemorrhagic stroke and stroke of unknown type. The decreases may be related to changes in risk factors, such as the decline in blood pressure and the decrease in cigarette smoking, as well as improvements in diagnosis and treatment. (Stroke. 1994;25:1170-1175.)

Key Words: • incidence • mortality • subarachnoid hemorrhage

Coronary heart disease (CHD) mortality in the United States has declined approximately 2.5% per year from the mid-1960s to the mid-1980s. The decline in stroke mortality began even earlier and has been steeper during the same years, at approximately 4% annually. In Japan the decline in stroke mortality started at a higher base and began later than in the United States, but it has shown an even steeper decline from 5.1 per 1,000 person-years in 1969 to 1972 to 2.4 in 1985 to 1988. The incidences of thromboembolic stroke, hemorrhagic stroke, and total stroke decreased 3.5%, 4.2%, and 4.4% per year, respectively. The 1-month case-fatality rates for thromboembolic stroke decreased moderately; those for hemorrhagic stroke fell dramatically.

Whether these changes reflect a decreased incidence of disease or a lower case-fatality rate cannot be determined from governmental statistics because there is no monitoring method for determining stroke incidence on a national basis. Estimates of incidence must be based on data from communities such as Rochester, Minn, or on ongoing cardiovascular disease cohort studies such as the Framingham Study.

Since 1966 the Honolulu Heart Program has monitored the incidence and mortality from CHD and stroke in a cohort of men of Japanese ancestry born from 1900 to 1919 and living on the island of Oahu, Hawaii. Questionnaires mailed to all those in the target population, 11,136 men early in November 1968. Both the 8,006 examined and 3,130 nonexamined men have been followed up for the occurrence of cardiovascular and selected other diseases, as well as for type-specific and total mortality. The purpose of the current study is to determine trends in stroke incidence and mortality during 20 years of follow-up.

Subjects and Methods Mortality rates were calculated separately for both examined and nonexamined men because of a possible difference between them in the risk of stroke. For the purpose of comparing mortality rates in our target population with rates compiled from vital statistics, the mortality rates of both groups were combined, including those known to have CHD or stroke at the initial examination. Incidence rates could not be compared because we counted only first episodes of stroke, and the stroke status of nonexamined men at the start of the study was indeterminable.

Details regarding the identification of the target population, the response to mailed questionnaires and to invitations for examination, and the techniques for follow-up have been published. Briefly, the target population was all of the 11,136 men of Japanese ancestry, born from 1900 through 1919, who were identified as living on the island of Oahu in 1964. Questionnaires were mailed to all those in the target population. In 1965, 9,877 questionnaires were returned, and all were invited to be examined; 8,006 agreed and were examined between October 1965 and November 1968. Comprehensive surveillance of hospital discharges, death certificates, and obituary notices of men meeting the birth and ethnic criteria has been ongoing, through 1982 for nonexamined men and continuing to the present for the examined cohort.

Decisions regarding occurrence of stroke, categorization by subtypes, and cause of death were made on the basis of detailed review of records. Hospital histories, physical examinations, neurological consultations, and discharge summaries were scrutinized. When performed, results and interpretations of cerebrospinal fluid exams, nuclear brain scans, electroencephalograms, duplex studies, and angiograms were available.

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for review. Computed tomography (CT) scans became available in 1976 and have been widely used since 1978. Attending physicians were contacted regarding their outpatient records when testing was done outside of a hospital or when patients were not hospitalized for their strokes.

The diagnosis of hemorrhagic stroke required the finding of blood in the cerebrospinal fluid or on CT scan. Subarachnoid hemorrhage was differentiated from cerebral hemorrhage by clinical findings as well as the results of either nuclear or CT scans or angiography. Thromboembolic strokes were diagnosed by intra-axial lesions in the absence of blood in the cerebrospinal fluid or on CT scan. CT diagnosis of infarction was limited to lesions that were clearly new and/or caused a shift or mass effect. CT readings were compared with readings from prior hospitalizations and/or prior stroke. Periventricular white matter lesions, old lacunar white matter lesions, and leukoaraiosis were not considered new infarctions. Lacunes developing in the correct location for symptoms and signs during the hospitalization and clearly not present on admission were identified as new reviews. CTs were considered infarcts. We could not consistently distinguish embolic from thrombotic strokes. Nuclear brain scan or flow studies performed late enough in the patient’s course to allow blood-brain barrier breakdowns were major diagnostic criteria for hemorrhagic and ischemic infarctions until the advent of CT scanning. Findings on all tests were combined when no single test was definitive. A single neurologist (J.P.) characterized and classified all the material to achieve optimal consistency.

Some associated conditions led to the exclusion of a stroke as a study stroke. These included the following: (1) precipitating conditions (eg, uremia); (2) mimics (eg, migraine, Todd’s paralysis, hypoglycemia); (3) bleeding (eg, blood dyscrasias, anticoagulant therapy); (4) trauma (especially cranial); (5) malignancies (eg, metastases, nonbacterial endocarditis, brain tumor); and (6) surgical strokes (eg, endarterectomy, coronary artery bypass graft, aortic aneurysm surgery, intracranial surgery, angiography). Strokes due to arteriovenous malformations, aneurysms, and other congenital abnormalities of the vascular apparatus were considered study strokes; subdural hematomas were not.

Men who had existing stroke at the time of the initial examination were included in the calculation of mortality rates but not in the calculation of incidence rates or case-fatality rates. For the calculation of case-fatality rates, the denominator consisted of all first-event strokes occurring within a given 4-year period. The numerator consisted of all deaths occurring within 30 days, 1 year, and 5 years after the date of stroke onset.

The nonexamined men had a higher stroke mortality than the examined men in the period from 1965 to 1968. The examined men in the population at risk for stroke incidence thus represented a relatively low-risk group for stroke incidence and mortality. This was caused by the disease- and self-selective elimination from the population at risk of those men who developed a stroke after the mailing of the questionnaire but before the end of the first examination in November 1968 and who did not come in for an examination, or of those men who developed a stroke between January 1965 (the time of the mailing of the questionnaire) and November 1968 and who came in for examination but had had the stroke before the examination. They thus fell into the category of stroke prevalence and were no longer eligible for the category of incidence of first episode of stroke. The healthy participant effect operating at a maximum through the first examination period makes it problematic to use the stroke data during that early period for analysis of trend. We have elected, therefore, to begin our trend analysis starting January 1, 1969.

We have used two statistical methods to calculate trends. The study subjects were classified into age-date categories of 1 year each, with each subject’s contribution to a given year based on his birthdate, and person-years at risk were calculated. Incident cases were tabulated by age and date of onset of the first event; fatal cases were tabulated by age and date of death. Age-adjusted rates for each year were calculated by an iterated proportional fitting process.7 Incidence rates were expressed as rates per 1000 person-years at risk. Estimation of the change in incidence over time was by standard yearwise logistic regression analysis of the probability of having a stroke during a calendar year among subjects at risk at the start of the year. Each subject contributed one record per year of observation until death, stroke, or the end of the follow-up, with the variable “age” for each record being the subject’s age at the start of that year. Presence or absence of an incident stroke was regressed on calendar year and subject’s age that year, using a logistic regression model.

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## Results

During the follow-up period there were 530 episodes of stroke among the 7893 men who were free of stroke at the initial examination (389 cases of thromboembolic stroke, 124 cases of hemorrhagic stroke, and 17 cases of stroke of unknown type).

Age-adjusted incidence rates for total stroke declined during the period of follow-up, from 5.1/1000 person-years in 1969 to 1972 to 2.4/1000 person-years in 1985 to 1988 (Fig 1). The trends for age-specific rates varied. The decline in rates was steeper for men younger than 70 years at the time of onset (Table 1). Rates increased at ages older than 80 years.

In the categories of type-specific stroke, incidence rates for thromboembolic stroke paralleled those for total stroke. Age-adjusted rates fell from 3.5/1000 person-years in the first 4-year period to 1.9/1000 person-years in the fifth period (Fig 1). As was true in the case of total stroke, the declining incidence trend for thromboembolic stroke was steeper for men younger than 70 years, and rates increased at ages 80 to 88 (Table 1).

Age-adjusted incidence rates for hemorrhagic stroke fell from the first follow-up period to the fifth period. The rates for the first and fifth periods were 1.1/1000 person-years and 0.6/1000 person-years, respectively (Fig 1). Age-specific rates did not show consistent trends (Table 1).
were 61.1% for strokes occurring in 1969 to 1972 and 40.8% for strokes occurring in 1985 to 1988. Corresponding rates for thromboembolic stroke were 55.2% and 36.8%; the rates for hemorrhagic stroke were 79.2% and 54.2%. In long-term follow-up, there was a shift in causes of death from stroke to CHD and other causes.

The distribution of stroke by subtype varied during the period of observation (Table 2). There was no change in the proportion of strokes due to intracerebral hemorrhage. There was a fall in the proportion of cases of subarachnoid hemorrhage from a high of 13% in 1973 to 1976 to a low of 0.8% in 1985 to 1988. Thromboembolic stroke increased from 69% in 1969 to 1972 to 80% in 1985 to 1988. The changes in the proportions of thromboembolic stroke and subarachnoid hemorrhage may reflect the changes in incidence associated with an aging cohort. It is well recognized that there is an increase in the proportion of thromboembolic stroke with increasing age, and the peak occurrence of rupture of berry aneurysms is among persons in their 50s. By 1980 none of our cohort was aged younger than 60 years.

Case-fatality rates also changed during the period of observation (Table 3). Death rates during the first 30 days after stroke occurrence fell from 29.9% in the first period to 16.4% in the fifth period. For thromboembolic stroke the corresponding figures were 12.9% (1969 to 1972) and 10.4% (1985 to 1988). For hemorrhagic stroke death rates were 74.8% in the first follow-up period and 28.7% in the fifth period (Fig 2).

Cumulative 1-year fatality rates for stroke consistently fell from 39.2% in 1969 to 1972 to 25.3% in 1985 to 1988. The corresponding rates were 23.7% and 19.6% for thromboembolic stroke and 76.5% and 34.8% for hemorrhagic stroke.

Cumulative 5-year mortality rates for total stroke were 61.1% for strokes occurring in 1969 to 1972 and 40.8% for strokes occurring in 1985 to 1988. Corresponding rates for thromboembolic stroke were 55.2% and 36.8%; the rates for hemorrhagic stroke were 79.2% and 54.2%. In long-term follow-up, there was a shift in causes of death from stroke to CHD and other causes.

The major improvement in survival after hemorrhagic stroke occurred within the first month after onset (Fig 2). For hemorrhagic stroke, improvement was greatest in the final 4-year follow-up period. For thromboembolic and total stroke the greatest improvement in 1-year survival occurred in the fourth follow-up period.

Stroke mortality rates were higher for nonexamined than for examined men in the period from 1965 to 1968, and this pattern persisted during the periods 1969 to 1972 and 1973 to 1976 (Fig 3), although this difference was not statistically significant. The rates were equivalent by 1977, and surveillance of nonexamined men was discontinued after 1982.

The trend in stroke mortality for Hawaiian Japanese men in our target population, combining examined and nonexamined men, paralleled the decline among US white men aged 60 to 69 years during the same follow-up period (Fig 4).

Logistic regression analysis revealed an age-adjusted mean annual decrease of 4.4%/y (<.0001) for total stroke incidence, 3.5%/y (<.005) for thromboembolic stroke incidence, and 4.2%/y (<.05) for hemorrhagic stroke incidence.

Similarly, 30-day case-fatality rates decreased at an average annual rate of 7.3% for total stroke (<.001), 3.6% for thromboembolic stroke (P=NS), and 8.7% for hemorrhagic stroke (<.005).

The 1-year case-fatality rates fell at an annual rate of 7.3% for total stroke (<.0002), 5.7% for thromboembolic stroke (<.05), and 7.4% for hemorrhagic stroke (<.02).

**Discussion**

These results indicate a decrease in stroke incidence of all types among the examined cohort. Similarly, there was a decline in mortality among both the examined and
nonexamined men. Figures compiled by the National Heart, Lung, and Blood Institute and the National Center for Health Statistics\(^1\) show that the decline in mortality continued through 1989.

The decrease in case-fatality rates in the first month after stroke onset was accompanied by a shift to a higher mortality in subsequent long-term follow-up, including a shift to CHD and other causes as underlying causes of death. This shift from early to later mortality was particularly striking for hemorrhagic stroke. Thirty-day case-fatality fell between the first and fourth follow-up periods, from 94.4% of all deaths to 56.3% of deaths. Overall, this resulted in decreased long-term total mortality after stroke.

There is general agreement that there has been a decline in stroke mortality for decades, which accelerated in the late 1960s and 1970s.\(^{13,11-15}\) There is disagreement regarding whether this decline slowed, stopped, or even reversed in the 1980s.\(^{15}\)

Cooper et al\(^{16}\) suggest that stroke mortality rates have leveled off, with equivocal suggestions of a recent increase in rates. Our data corroborate this tendency (Fig 3). Additional follow-up data are required to determine whether this represents a new trend in the Honolulu Heart Program cohort or only a temporary increase in the otherwise continuous downward trend indicated by national statistics.\(^1\)

There is also disagreement regarding whether the decline in mortality has been accompanied by a decline in incidence. The spectrum of findings ranges from a reported increase in Canadian\(^ {17}\) and Danish\(^ {18}\) studies to a decline in incidence in the Rochester study,\(^3\) Japanese studies,\(^ {19-21}\) and a Finnish study.\(^ {22}\)

Some of the differences may be attributable to the fact that some studies define as incident cases only first-ever stroke events,\(^ {23,24}\) while others are studies of morbidity that include recurrent events.\(^ {25,27}\) In general, the true incidence studies, especially among persons of Japanese ancestry, have shown the sharpest declines. In the case of the Framingham Study,\(^ {4}\) a true incidence study, there was a close to significant decline in incidence of completed strokes only in women (\(P=0.07\)). There was a significant decline in the 1-year case-fatality rates in men, but this occurred concurrently with a significant increase in the proportion of transient ischemic attacks, which were included in the case mix. In most other studies only completed strokes with a duration of neurological signs of greater than 24 hours were counted.

It is possible that the trend in incidence varies according to ethnic groups, but the Scandinavian experience does not support this hypothesis. The Rochester population includes a high proportion of persons of Scandinavian ancestry. The Rochester\(^1\) and Finnish\(^ {22}\) studies showed a decline in stroke incidence. Conversely, a Swedish study\(^ {28}\) found no decline in incidence rates, and a Danish study\(^ {18}\) showed an increased incidence.

It has also been suggested that population-based studies are more appropriate for the assessment of trends than cohort studies. The Rochester study, for example, is a population-based study, while the Honolulu Heart Program is a longitudinal cohort study. Each type has its advantages, but it is not clear that a series of cross-sectional studies in a single population is preferable to a long-term incidence study in assessing trends. The suggestion that the population in a population-based study is more stable than that in a cohort study is debatable. The Honolulu Heart Program target population had, by definition, no immigration, and it has experienced less than 0.1% outmigration.

### Table 2. Distribution of Strokes by Subtype

<table>
<thead>
<tr>
<th>Years of Follow-up</th>
<th>Total</th>
<th>Thromboembolic</th>
<th>Intracerebral Hemorrhage</th>
<th>Subarachnoid Hemorrhage</th>
<th>Unknown Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969-1972</td>
<td>96</td>
<td>66 (69)</td>
<td>16 (17)</td>
<td>8 (8)</td>
<td>6 (6)</td>
</tr>
<tr>
<td>1973-1976</td>
<td>100</td>
<td>65 (65)</td>
<td>17 (17)</td>
<td>13 (13)</td>
<td>5 (5)</td>
</tr>
<tr>
<td>1977-1980</td>
<td>98</td>
<td>71 (72)</td>
<td>18 (18)</td>
<td>7 (7)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>1981-1984</td>
<td>112</td>
<td>88 (79)</td>
<td>18 (16)</td>
<td>4 (4)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>1985-1988</td>
<td>124</td>
<td>99 (80)</td>
<td>22 (18)</td>
<td>1 (0.8)</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Total</td>
<td>530</td>
<td>389 (73)</td>
<td>91 (17)</td>
<td>33 (6)</td>
<td>17 (3)</td>
</tr>
</tbody>
</table>

Values in parentheses are percentages.
One problem in the interpretation of trends in type-specific stroke incidence and mortality was the introduction of new diagnostic technology during the study period. In particular, CT scanning came into use in 1976 (it was used in 6 of 28 cases that year), and in succeeding years its use rose to approximately 95% of hospitalized cases.

Although the advent of CT scans in the mid-1970s was an advance for subtype classification, there was no substantial change in our ability to determine stroke incidence. Because the majority of CT scans were performed too early in the patients’ course for conclusive evidence of cerebral infarction, the major impact was to increase somewhat the specificity of the diagnoses of cerebral and subarachnoid hemorrhage and to reduce somewhat the proportion of stroke of unknown type.

During the current study there has been a change in risk factors in the cohort. An examination of a 30% subsample 15 years after the initial examination showed a significant decrease in blood pressure levels among treated hypertensive subjects. There was also a significant decrease in the percentage of men who smoked cigarettes. In addition, there were changes in dietary habits, with declines in the intakes of animal protein and cholesterol and an increase in the intake of vegetable protein. There was also a nominal but statistically insignificant decrease in both saturated and polyunsaturated fatty acid intake, an increase in monounsaturated fatty acid intake, and an increase in carbohydrate intake.

Another piece of evidence supporting the hypothesis that the fall in stroke mortality is the result, at least in part, of a decline in incidence is supplied by the findings of a decline in severity of atherosclerosis in the circle of Willis between 1967 and 1982 among those who died and were autopsied.

Although we may derive satisfaction from the trends in stroke incidence (probable) and mortality (certain), it is not clear who, if anyone, can claim credit for their occurrence. Is the decrease part of a change (perhaps cyclical) in the natural history of cardiovascular disease in general and of stroke in particular such that both the frequency and severity of stroke have declined without any relation to change in human societal behaviors? Is the change attributable to a general improvement in the standard of living among developed nations in recent decades, including better housing and better nutrition?

Alternatively, the epidemiological research and public health communities can lay claim to the elucidation of risk factors for CHD and stroke and for the promotion of more healthful behaviors to modify these risk factors, including improved nutrition, decreased cigarette smoking, improved control of high blood pressure, and a resultant decrease in the frequency, and perhaps severity, of stroke.

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**TABLE 3. Stroke Case-Fatality Age-Adjusted Rates in the Honolulu Heart Program Examined Cohort**

<table>
<thead>
<tr>
<th>Years</th>
<th>No. of Cases</th>
<th>Cumulative Fatality</th>
<th>No. of Cases</th>
<th>Cumulative Fatality</th>
<th>No. of Cases</th>
<th>Cumulative Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 d 1 y 5 y</td>
<td></td>
<td>30 d 1 y 5 y</td>
<td></td>
<td>30 d 1 y 5 y</td>
<td></td>
</tr>
<tr>
<td>1969-1972</td>
<td>66</td>
<td>12.9 23.7 55.2</td>
<td>24</td>
<td>74.8 76.5 79.2</td>
<td>96</td>
<td>29.9 39.2 61.1</td>
</tr>
<tr>
<td>1973-1976</td>
<td>65</td>
<td>12.6 27.7 45.3</td>
<td>30</td>
<td>53.2 54.2 57.2</td>
<td>100</td>
<td>25.9 36.6 50.2</td>
</tr>
<tr>
<td>1977-1980</td>
<td>71</td>
<td>10.9 19.9 45.8</td>
<td>25</td>
<td>40.8 59.9 65.5</td>
<td>98</td>
<td>20.3 32.3 52.3</td>
</tr>
<tr>
<td>1981-1984</td>
<td>88</td>
<td>6.7 13.9 44.8</td>
<td>22</td>
<td>37.3 51.7 70.0</td>
<td>112</td>
<td>13.7 23.1 50.2</td>
</tr>
<tr>
<td>1985-1988</td>
<td>99</td>
<td>10.4 19.6 36.8</td>
<td>23</td>
<td>28.7 34.8 54.2</td>
<td>124</td>
<td>16.4 25.3 40.8</td>
</tr>
</tbody>
</table>

Values are percentages.
In addition, the medical community can claim its contribution to promoting a healthier lifestyle, to improved treatment of high blood pressure, and when these do not succeed in preventing stroke, to improved diagnosis and treatment, leading to improved case-fatality rates and overall mortality.

These speculations are complicated by the fact that other studies, although confirming a decline in mortality, do not all confirm a decline in incidence. As noted above, studies in Rochester, Framingham, Finland, Sweden, and Denmark do not agree on trends in stroke incidence. Other studies analyzed morbidity data, including recurrent events, whereas the Rochester and the Honolulu studies counted only first events for incidence.

The current study can only contribute to the formulation of a model describing the contribution of a decline in incidence to the decline in mortality. Further studies, both of a data-gathering and of a synthesizing nature, are required to achieve such a formulation.

We cannot yet know whether we have reached the nadir of stroke mortality, whether further improvement is in store.

Acknowledgments

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References

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