Incidence Rates of Stroke in the Eighties: The End of the Decline in Stroke?

Joseph P. Broderick, MD, Stephen J. Phillips, MD, Jack P. Whisnant, MD, W. Michael O’Fallon, PhD, and Erik J. Bergstralh, MS

Studies of the population of Rochester, Minnesota, have provided the only data on temporal trends for the incidence of stroke in North America. Among the residents of Rochester, the average annual incidence rate of stroke declined by 46%, from 213 to 115 per 100,000 population, between 1950-1954 and 1975-1979. The decline occurred in all age and sex groups, but it occurred earlier in women than in men. The rates stabilized in the 1970s, and did so earlier in women. For 1980–1984, the incidence rate of stroke was 17% higher than that for 1975–1979. The onset of the decline in incidence rates coincided with the introduction of effective antihypertensive therapy, but stabilized and increased rates were associated with continuing improvement in the control of hypertension. The increase in the incidence rates of stroke coincided with the introduction of computed tomography, which appeared to increase the detection of less severe strokes. (Stroke 1989;20:577–582)

Studies of the population of Rochester, Minnesota, have provided the only available data concerning temporal trends for the incidence of stroke in North America. We report the incidence rates for first stroke during the period 1980–1984 and amended data concerning the incidence of stroke during the years 1945–1979.

Subjects and Methods

Medical care for residents of Rochester and the surrounding area has been centered at the Mayo Clinic since the beginning of this century. Each patient’s medical record contains a master sheet that lists all diagnoses for that patient (whether they were made in the hospital, in the outpatient clinic, at a home visit, or at autopsy). These diagnoses are coded and entered into a computer file that also includes diagnoses for Rochester residents that were made at other medical facilities in and around Olmsted County. This medical records and records-linkage system was used to retrieve the records of all residents of Rochester who were diagnosed as having stroke, or disorders that could be mistaken for stroke, during the 5-year period January 1, 1980, through December 31, 1984. All potential cases were screened by a trained nurse abstractor under daily supervision by a neurologist. Cases of first stroke were identified by the following criteria.

Cerebral infarction. A focal neurologic deficit of acute onset, persisting for >24 hours, that could not be attributed to another disease process. Patients who, ≥24 hours after the onset of stroke, had only persistent sensory symptoms with minimal sensory signs or mild impairment of dexterity with normal muscle strength were included. Patients who, after 24 hours, had only deep tendon reflex changes or Babinski’s signs were excluded. Computed tomography (CT) of the head or autopsy, when performed, did not show evidence of an intracerebral hematoma.

Intracerebral hemorrhage. A focal neurologic deficit of acute onset that was associated with vomiting, altered level of consciousness, signs of meningeal irritation, or blood-stained cerebrospinal fluid. CT of the head or autopsy, when performed, demonstrated an intracerebral hemorrhage.

Subarachnoid hemorrhage. Abrupt onset of severe headache or coma that was associated with signs of meningeal irritation and blood in the subarachnoid space. CT or autopsy, when performed, showed blood in the subarachnoid space. Parenchymal bleeding that extended into the subarachnoid space was classified as intracerebral hemorrhage.

Stroke of unknown type. Clinical evidence of stroke but insufficient information for a pathologic diagnosis.
Potential cases of stroke were excluded if 1) the patient had no clinical history of stroke and the only evidence of a stroke was a diagnosis on the death certificate, an area of low density on a CT head scan, or an old lesion in the brain at autopsy; a recent lesion in the brain at autopsy was considered stroke, regardless of the history; 2) the patient had a clinical diagnosis of stroke and died within 24 hours of the onset of symptoms and had no focal neurologic deficit, no autopsy, and no CT head scan; or 3) the patient had lived in Rochester for <1 year before the first stroke. Preliminary results indicated that the incidence rates for first stroke for 1980–1984 were significantly higher (p<0.05) than the rates for the previous 5-year period—a reversal of the 25-year decline in the incidence rates of stroke for the Rochester population.4,5 This observation prompted us to consider whether there were procedural differences in case ascertainment between 1980–1984 and the earlier 5-year study periods. For this reason, potential cases of stroke that occurred during the period 1945–1979 were reevaluated using the same inclusion and exclusion criteria, the same nurse abstractor, and the same process of supervision. Consequently, several cases of transient ischemic attacks were reclassified as strokes, and the incidence rates for the period 1945–1979 reported here differ somewhat from those published previously.4,5 The records of all identified patients with first stroke during 1945–1984 were abstracted by a neurologist.

Average annual age- and sex-specific incidence rates were calculated over consecutive 5-year periods for all strokes and for cerebral infarction. Strokes of unknown type were considered cerebral infarctions. The average annual incidence rates of cerebral infarction, intracerebral hemorrhage, and subarachnoid hemorrhage were calculated over consecutive 10-year periods because of the relatively few hemorrhagic events. Trends in the incidence rates of all strokes were also examined by calculating average annual rates for consecutive, overlapping 3-year intervals (that is, 1945–1947, 1946–1948, 1947–1949, and so on, through 1982–1984). The person-years that were used as the denominators in these calculations were interpolated from decennial census data. All incidence rates were adjusted to the 1970 US white population.

To determine whether the difference in temporal trend in incidence rates for men and women was statistically significant, Poisson regression was used on the 112 crude incidence rates formed by all combinations of sex, 5-year period (1945–1949, 1950–1954, 1955–1959, 1960–1964, 1965–1969, 1970–1974, 1975–1979, and 1980–1984), and age group (<35, 35–44, 45–54, 55–64, 65–74, 75–84, and ≥85 years).6 The natural logarithm of the crude rates was modeled as a linear combination of sex, age group, and 5-year period effects using the GLIM software package.7 The model deviance (which is a measure of how well the observed and predicted incidence rates agree) was used as a means of assessing model fit. The expected value of the deviance is approximately equal to its degrees of freedom (which are equal to 112—p, where p is the number of parameters in the model) if the model fits the data reasonably well. We also examined plots of observed vs. predicted incidence rates to assess the adequacy of specific models. When comparing the nested models, we used the fact that the change in the deviance has an approximate χ² distribution with degrees of freedom equal to the difference in the number of parameters in the two models. All probability values were two-sided, and they were significant if p≤0.05.

Results

During the period 1945–1984, 2,466 incidence cases of first stroke were identified in the population of Rochester. For the period 1980–1984, the average annual age- and sex-adjusted incidence rate of all strokes was 135 per 100,000 population. This rate is 17% higher than that for 1975–1979 but is 37% lower than the rate for 1950–1954. Between 1950–1954 and 1975–1979, the incidence of stroke declined by 46% (Table 1). Calculation of overlapping 3-year average annual incidence rates for men and women (Figure 1) showed that the end of the decline in inciden ce rates was in the late 1960s or early 1970s for women and in the mid-1970s for men. This temporal pattern of a decline followed by a recent increase was apparent in all age- and sex-specific rates (Table 2, Figure 2). The incidence rate of stroke increased with increasing age in all quintennia. Changes in incidence rates, both the earlier decline and the recent increase, were most marked among subjects ≥85 years old.

Between 1950–1954 and 1965–1969, the average annual incidence rates of stroke decreased from 210 to 103 per 100,000 (a decline of 51%) in women and
from 210 to 200 per 100,000 (a decrease of 5%) in men. Between 1965-1969 and 1975-1979, the incidence of stroke among women declined a further 7%, whereas the rates for men declined by 30%. The increase in incidence rates between 1975-1979 and 1980-1984 was 15% for women and 19% for men (Table 1, Figure 1).

Using Poisson regression, we investigated the effects of sex, age group, and 5-year period on the natural logarithm of the incidence rate of stroke. The model with all three effects had a deviance of 156.6 on 97 degrees of freedom. Each effect contributed significantly to the model fit. The addition of these two interaction terms were significant: sex×age group and sex×5-year period. The increase in incidence rates between 1975-1979 and 1980-1984 was 15% for women and 19% for men (Table 1, Figure 1).

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FIGURE 1. Overlapping 3-year average annual incidence rates of first stroke in Rochester, Minnesota, 1945–1984. Rates were age-adjusted to 1970 US white population. □, men; ●, women.

For the period 1980–1984, the average annual incidence rate of cerebral infarction was 112 per 100,000 population. This is 22% higher than the rate for 1975–1979 but is 40% lower than that for 1950–1954. The trends in incidence rates for men and women were similar to those for all stroke types (Tables 3 and 4). The average annual incidence rate of intracerebral hemorrhage for the period 1975–1984 was 14 per 100,000 population. This rate is the same as that for 1955–1964 but is higher than the rate for 1965–1974 (Table 4). Trends in incidence rates for men and women were similar. The incidence rates of subarachnoid hemorrhage have changed little since 1945. For the period 1975–1984, the average annual incidence rate was 10 per 100,000 population (Table 4).

FIGURE 2. Predicted age-group–specific incidence rates of first stroke for men (top) and women (bottom) in Rochester, Minnesota, from Poisson regression model. ●, <35; □, 35–44; ■, 45–54; △, 55–64; ▲, 65–74; ○, 75–84; ●, ≥85 years old.

TABLE 2. Average Annual Age-Specific Incidence Rates of Stroke per 100,000 Population of Rochester, Minnesota, During Various Periods From 1945 Through 1984

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<td>247 51 179 39</td>
<td>209 46</td>
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<td>75–84</td>
<td>1,207 99 1,306 99</td>
<td>1,207 114 1,098 117</td>
<td>1,113 122 1,137 122</td>
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<td>≥85</td>
<td>2,280 34 1,388 29</td>
<td>1,324 37 1,140 40</td>
<td>1,837 75</td>
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TABLE 3.  Average Annual Incidence Rates* of Cerebral Infarction† per 100,000 Population of Rochester, Minnesota, During Various Periods From 1945 Through 1984

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<thead>
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<th>Period</th>
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<td>427</td>
<td>161</td>
<td>536</td>
<td>115</td>
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<td>102</td>
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<td>1955-1964</td>
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<td>51</td>
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<td>47</td>
<td>9</td>
<td>42</td>
<td>14</td>
<td>80</td>
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<tr>
<td>1965-1974</td>
<td>10</td>
<td>26</td>
<td>12</td>
<td>43</td>
<td>12</td>
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<td>10</td>
<td>56</td>
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* Rates are adjusted for age and sex to the 1970 US white population.
† Includes stroke of uncertain type.
‡ Age-adjusted to the 1970 US white population.

The proportion of persons with stroke who had a CT of the head increased progressively during the 1970s and 1980s (Figure 3). Most of the increase occurred between the 3-year periods 1974-1976 and 1980-1982. The increase in CT usage occurred at about the same time as the plateau for incidence rates of stroke. However, the incidence rates of stroke among women leveled out between 5 and 10 years before substantial use of CT.

The proportion of patients who died within 30 days of stroke onset decreased from 33% during 1945-1949 to 17% during 1980-1984 (Table 5). This decrease in the case-fatality rate was more marked in patients younger than 70 years than in older patients; however, the trend was highly significant for both groups (p<0.001, Mantel-Haenszel χ² test).* The significant decrease in 30-day mortality for patients with intracerebral hemorrhage (p<0.001, Mantel-Haenszel χ² test) coincided with the introduction of CT and the identification of milder cases. There was also a significant but borderline trend toward reduction of the 30-day mortality from subarachnoid hemorrhage (p=0.047, Mantel-Haenszel χ² test) that began in the 5-year period before the introduction of CT.

The proportion of persons with stroke who were ≥65 years old during each quinquennium increased from 67% in 1945-1949 to 77% in 1980-1984 (p<0.001, Mantel-Haenszel rank χ² test) (Table 6). The proportion of persons with intracerebral hemorrhage in this age group increased from 52% to 71% during the same time period (p=0.007, Mantel-Haenszel rank χ² test). This trend was not observed for subarachnoid hemorrhage (p=0.574, Mantel-Haenszel rank χ² test).

**TABLE 4. Average Annual Incidence Rates* of Categories of Stroke per 100,000 Population of Rochester, Minnesota, During Various Periods From 1945 Through 1984**

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<td>102</td>
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<tr>
<td>Intracerebral hemorrhage</td>
<td>20</td>
<td>51</td>
<td>14</td>
<td>47</td>
<td>9</td>
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<td>14</td>
<td>80</td>
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<tr>
<td>Subarachnoid hemorrhage</td>
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* Rates are adjusted for age and sex to the 1970 US white population.
† The sum of the categories of strokes in this table is a slightly larger number than the total number of all strokes in Tables 1 and 2 because a few patients had both an infarction and a hemorrhage and only the first category was counted for all strokes.
‡ Includes stroke of uncertain type.

**Discussion**

The incidence rate of stroke in Rochester, Minnesota, is no longer declining. The decline started earlier for women than for men, and the rates showed an earlier plateau in women. Incidence rates of stroke for both sexes increased for 1980-1984 compared with the previous quinquennium. This difference in the trends of rates for men and women was significant (p=0.0076, Figure 1). The decline and the recent increase were noted for all age-sex-specific rates, but they were most prominent in the older age groups (Figure 2).

Two important factors that seem to have affected the trends in incidence rates of stroke during the 40-year study period were the decreasing prevalence of untreated hypertension in the Rochester population and the introduction of CT scanning.

The decline of stroke in Rochester began at approximately the same time that the control of hypertension improved in the community. However, the control of hypertension among Rochester residents continued to improve during the 1970s and 1980s, whereas the incidence rate of all strokes stabilized or increased. The effect of hypertension control on stroke incidence obviously has limitations, but whether changes in other potential risk factors have contributed to the observed trends in incidence rates of stroke in Rochester has not been determined.

The changes in incidence rates of cerebral infarction are similar to the changes in incidence rates of all strokes. Thus, statements concerning the role of hypertension in the decline of all strokes also apply to cerebral infarction. Whether the trends in inci-
Incidence rates for each of the major pathogenetic subtypes of cerebral infarction (for example, atherothromboembolism, cardiogenic embolism, hypertension-associated small-vessel disease) mirror the incidence trends for all cerebral infarction remains to be established.

It could be argued that the end of the decline in stroke for Rochester is an artifact due to increased case ascertainment by CT scans. The use of CT has occurred at the same time as the increase in the use of CT to the increase in incidence rates of stroke. The increase in incidence rates of stroke observed in the early 1980s occurred at the same time as the increase in the use of CT.

To better estimate the potential contribution of CT to the increase in incidence rates of stroke during the late 1970s and 1980s, a trained abstractor re-reviewed all cases of stroke for 1979. Of 70 new cases of stroke in 1979, there were two cases for which the CT scan of the head was essential for the correct diagnosis of stroke. This medical record review very likely underestimates the impact of CT on the incidence rates of stroke. CT scanning is often the first screening test used by physicians for any patient with suspected neurologic symptoms. Abnormalities on the CT scan may prompt further investigation of the patient's history (that is, the clinical history compatible with stroke may be elicited as a result of an abnormality on the CT scan). All incidence rates before the introduction of CT are probably underestimates, but the extent of this underestimate is not possible to determine.

The stabilization in incidence rates of stroke for women in the early 1970s preceded the introduction of CT. However, the increased use of CT in the late 1970s and 1980s may be partly, if not largely, responsible for the subsequent increase in incidence rates of stroke. Data from the National Hospital Discharge Survey support the impact of CT on case ascertainment of stroke. This survey demonstrated an increase in hospital discharge rates for cerebrovascular disease during 1979–1984 with a concomitant decrease in hospital case-fatality rates. During 1979–1982, the rate of CT scans of the head among patients discharged from US hospitals tripled. The Rochester study and the National Hospital Discharge Survey indicate that any study of the incidence rates of stroke that is done during a time when the rate of use of CT is changing must account for the impact of CT.

CT scanning also affected the incidence rates of stroke categories (for example, intracerebral hemorrhage and cerebral infarction). The incidence rate of intracerebral hemorrhage for 1965–1974 (before CT) was 36% lower than that for 1955–1964, and the rate for 1975–1984 (CT era) was 56% greater than that for 1965–1974. This increase in the incidence rate of intracerebral hemorrhage during the CT era is largely due to the detection of small hemorrhages by CT with an associated decrease in the case-fatality rate for intracerebral hemorrhage. These small intracerebral hemorrhages would have been categorized as cerebral infarcts before the use of CT.

Since the early 1980s, nurse health-practitioners have provided much of the routine medical care for nursing home patients in the Rochester area. However, increased surveillance of this high-risk group does not explain the increase in the incidence rates of stroke between 1975–1979 and 1980–1984. The proportion of patients ≥85 years old who had their first stroke detected while living in a nursing home was essentially the same for 1980–1984 (18 of 74 patients, 24%) as for 1975–1979 (nine of 41 patients, 22%) ($p=0.8$).

The improvement in 30-day case-fatality rates for stroke in recent quinquennia could represent an actual decrease in early stroke mortality, an increased detection of milder cases of stroke in the

### Table 5. Trends in 30-Day Mortality From Stroke in Rochester, Minnesota, During Various Periods From 1945 Through 1984

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<td>88</td>
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<td>89</td>
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<tr>
<td>Subarachnoid hemorrhage</td>
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<td>44</td>
<td>67</td>
<td>58</td>
<td>45</td>
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<td>42</td>
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Data are %.

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**Figure 3.** Overlapping 3-year average annual incidence rates for first stroke (○) and proportion of persons with first stroke who had computed tomography (CT) of the head (●) in Rochester, Minnesota, 1945–1984. Incidence rates were age- and sex-adjusted to 1970 US white population.
population, or both. Some of the improvement in 30-day survival occurred during the period of the study in which the incidence rate of stroke declined; this observation suggests that increased detection of milder strokes was not the only reason for the observed change in the case-fatality rate (Table 5). A previous Rochester study noted that almost all of the moderate improvement in 30-day stroke mortality for cerebral infarction occurred 5–21 days after the onset of stroke, with little difference noted at 3 days.14 This finding suggests that the improvement in short-term stroke mortality is due primarily to a reduction in the secondary complications of stroke (for example, aspiration pneumonia) rather than to any improvement in the treatment of acute brain damage resulting from stroke. The marked decrease in 30-day mortality for intracerebral hemorrhage was closely associated with the introduction of CT.

The observation that the proportion of strokes that occurred among persons ≥65 years old significantly increased over time reflects the changing demographics of the Rochester population, and it has clear implications for future therapeutic endeavors (Table 6). Much of the previous focus for the prevention and therapy of stroke has been in younger patients; for example, only one of the several completed prospective trials of antihypertensive therapy included subjects >70 years old, and current carotid endarterectomy trials exclude patients >75 years old.15 The Rochester data demonstrate the potential impact of exclusion by age on patient recruitment in stroke treatment trials. For instance, if in a future therapeutic trial for cerebral infarction in the population of Rochester we excluded all patients ≥75 years old, we would eliminate 53% of potential candidates.

The exception to the aging of stroke patients is subarachnoid hemorrhage. Only 17 (30%) of 56 patients with a subarachnoid hemorrhage during 1975–1984 were ≥65 years old. Neither the incidence nor the typical age at onset of subarachnoid hemorrhage changed significantly during the period 1945–1984 (Table 6). The lack of concordance in incidence trends between subarachnoid hemorrhage and other stroke categories indicates that the risk factors for subarachnoid hemorrhage are probably different than those for cerebral infarction and intracerebral hemorrhage.

### References


### Table 6. Trends in Age of Stroke Patients in Rochester, Minnesota

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<td>53</td>
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Data are %≥65 years old.

*p<0.05.

KEY WORDS • cerebrovascular disorders • incidence • hypertension
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