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This study has attempted to identify all patients in the population of Rochester, Minnesota, who had stroke during the period 1955 through 1969, and to determine the course and survival of patients who have had stroke. Cerebral infarction from all causes, including embolic infarction, accounted for 79% of all strokes. Intracerebral hemorrhage accounted for 10% of the cases, and subarachnoid hemorrhage accounted for 6%. The average annual incidence rate for the 15 years of the study was 164 per 100,000 population per year. The rates for all strokes and for cerebral infarction were significantly higher for men than for women, except in the youngest age group. After the end of an earlier study, 1945 through 1954, the average annual incidence rate for all strokes decreased in each succeeding five-year interval and reached 141 during the period 1965 through 1969. The decrease in rates is apparent for all strokes and for cerebral infarction, and is more apparent for women than for men. The prevalence rate on January 1, 1960, and January 1, 1965, of about 700 per 100,000 population was higher than the rate for January 1, 1970, reflecting decreasing incidence rates. A study of the functioning capacity of survivors of stroke after six months indicates that only 4% required total care and nearly 30% were functioning normally. Fifty-four percent had some neurological deficit that may have been benefited by rehabilitative care. Aphasia was an important residual incapacity in 10%. The first-year recurrence rate of stroke was 10%, and the five-year recurrence rate was 20%. Among patients with stroke who died, 38% died of the initial stroke, 10% of a subsequent stroke, and 18% of heart disease. During the 25-year period, 1945 through 1969, there has been a trend toward gradually increasing survival for cerebral infarction in this community.

Additional Key Words incidence prevalence mortality death certificate cerebral infarction cerebral hemorrhage subarachnoid hemorrhage stroke recurrence population study survivorship functioning capacity

Introduction

This report describes an additional 15 years of experience to the recently published "Natural History of Stroke in Rochester, Minnesota, 1945 Through 1954." This study covers the period 1955 through 1969. It was designed to determine trends in incidence, prevalence, and survivorship for various types of stroke and to judge risk factors associated with stroke. The study of the risk factors is not part of this report.

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A medical record indexing and retrieval system, similar to that used at the Mayo Clinic for several decades, has been established in all of the other medical institutions in and around Rochester. Therefore, identification is assured of practically all Rochester residents who received medical attention for stroke in any care unit in the community. This includes patients who were seen in the hospital, at the time of an office visit or house call, or at autopsy.

In the earlier period (1945 through 1954), more than 95% of patients with stroke were seen by physicians at the Mayo Clinic. In the mid-1950s, the Olmsted Medical Group began practice and the Olmsted Community Hospital was built. After that time an increasing percentage of Rochester residents received their primary care in one of these facilities.
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Therefore, in this current study (1955 through 1969) only 83% of patients with stroke were seen by physicians at the Mayo Clinic. However, our cases are derived from the records of all the institutions.

Transient ischemic attacks were not included in the early report and will be considered in a separate report for the period 1955 through 1969.

The total population of Rochester was 32,600 in 1955, as estimated by intercensus interpolation. It was 39,012 in 1960, 46,698 in 1965, 51,267 in 1969, and 52,629 in 1970; the 1960 and 1970 population figures are based on the decennial censuses corrected by subtracting the number of non-Rochester patients in the Rochester State Hospital.

Methods

All medical records for the population of Rochester, Minnesota, from the Mayo Clinic and other medical facilities in Olmsted County and also medical records from the University of Minnesota Hospitals and the Veterans Administration Hospital in Minneapolis and hospitals in southeastern Minnesota for residents of Rochester were reviewed for the 15-year period 1955 through 1969. Records were retrieved for patients whose diagnosis might have been stroke. For convenience, all categories of cerebrovascular disease collectively will be called strokes.

The following criteria were used to place patients into the various diagnostic categories of stroke:

Cerebral thrombosis—relatively rapid onset of focal neurological deficit persisting for longer than 24 hours and with clear cerebrospinal fluid. Included in this category are all cases of cerebral infarction not associated with a recognized source for an embolus.

Cerebral embolus—abrupt onset of focal neurological deficit in association with a known source for embolus. Because of this limitation, the number of embolic lesions probably are understated. A few red blood cells in the spinal fluid did not preclude this diagnosis.

Intracerebral hemorrhage (some or all of the following)—rapidd progression of focal neurological deficit, headache, altered state of consciousness, and evidence of meningeal irritation and gross blood in the spinal fluid.

Primary subarachnoid hemorrhage—abrupt onset of headache with or without altered consciousness, with signs of meningeal irritation, without focal neurological deficit, or with late occurrence of such deficit after other criteria were observed.

Type unknown—incomplete clinical details at the onset of the acute episode, but a history of onset and residual deficit sufficiently well documented to ensure a high likelihood that stroke had occurred.

The authors reviewed all the records and put the patients in the diagnostic categories according to the best information available. If an autopsy was performed, the information obtained was a determining factor in placing the patient into a diagnostic category.

Death certificates of residents of Rochester who died during the period 1955 through 1969 were reviewed to identify those with stroke. For those with a diagnosis of stroke, the clinical records were reviewed.

In 27 cases in which stroke was listed on the death certificate, either death occurred suddenly (less than two hours after the episode) or the elapsed time before death occurred was unknown, and autopsies were not performed. Because of the short time between onset of symptoms and death, these cases were presumed to have been nonstroke deaths and are not included. Also excluded were an additional 46 cases with the diagnosis of stroke on the death certificate in which the clinical records did not support the diagnosis or in which no clinical record was available.

All autopsy protocols from the Mayo Clinic facilities and the Olmsted Community Hospital for patients who died during the period 1955 through 1969 were reviewed, and patients were selected who were residents of Rochester and who had pathological evidence of stroke. When available, the clinical records of these patients also were reviewed. Twelve persons died before being admitted to a medical facility but all had pathological evidence of stroke, such as subarachnoid hemorrhage, intracerebral hemorrhage, or a recent large infarct. Eleven other patients had pathological evidence of a recent stroke but their clinical records revealed insufficient evidence for the diagnosis. These 23 cases were included in the analysis.

An additional 261 cases had autopsy evidence of an old infarct, old hemorrhage, or occlusion of a cerebral blood vessel, but had no documentation of a clinical event that might have been a stroke. These 261...
cases are excluded from analysis because there was no known clinical event and the date of any possible stroke could not be determined accurately.

For the determination of incidence, only patients whose first stroke occurred from January 1, 1955, through December 31, 1969, were considered. Studies of death certificates include only those of persons who had had a stroke at any time and who died between the period 1955 through 1969 while a resident of Rochester. Prevalence rates were determined by identifying all patients who had had a stroke and who were alive and residents of Rochester on January 1 of three selected years: 1960, 1965, and 1970.

A total of 1,245 patients were accepted for the study on the basis of diagnosis and residence (table 1). In 993 cases, the first stroke occurred while the patient was a resident of Rochester during the period 1955 through 1969. Studies of incidence rates and survivorship are based only on data from these patients, 83% of whom were seen by physicians at the Mayo Clinic. Studies concerning death certificates and autopsy diagnoses were based on data from 851 patients, each of whom had a stroke at some time and died while a resident of Rochester during the period 1955 through 1969 but who may not have been a resident at the time of stroke onset. Prevalence rates are based on the number of patients who had stroke and who were residents of Rochester on the selected dates. No patient was lost to follow-up.

**Results**

**INCIDENCE**

The incidence rates for stroke were higher for men than for women in each age group and were significantly higher for men more than 35 years of age (table 2). The rates for cerebral infarction in all locations (including embolic infarction) were higher for men than for women and were significantly so for men 35 through 74 years of age (table 3). These rates were based on clinical diagnoses, but in more than 50% of the deaths, autopsy confirmation was obtained.

Cerebral infarction from all causes including embolic infarction accounted for 79% of all strokes. The percentage of strokes attributed to embolic infarction (8%) is undoubtedly understated because it includes only cases in which a source for an embolus was recognized. Intracerebral hemorrhage accounted for 10% of the cases and subarachnoid hemorrhage for 6%. The type was unknown in 5% of the cases, but in most of these undoubtedly there was cerebral infarction of some type (table 4).

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**Table 2**

<table>
<thead>
<tr>
<th>Age group (yr)</th>
<th>Males No.</th>
<th>Rate</th>
<th>Females No.</th>
<th>Rate</th>
<th>Total No.</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;35</td>
<td>6</td>
<td>3</td>
<td>10</td>
<td>5</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>35-44</td>
<td>15</td>
<td>43</td>
<td>10</td>
<td>27</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>45-54</td>
<td>104</td>
<td>511</td>
<td>75</td>
<td>261</td>
<td>179</td>
<td>364</td>
</tr>
<tr>
<td>55-64</td>
<td>147</td>
<td>1,082</td>
<td>127</td>
<td>603</td>
<td>274</td>
<td>791</td>
</tr>
<tr>
<td>65-74</td>
<td>163</td>
<td>2,504</td>
<td>269</td>
<td>1,988</td>
<td>432</td>
<td>2,156</td>
</tr>
<tr>
<td>≥75</td>
<td>478</td>
<td>165</td>
<td>515</td>
<td>146</td>
<td>993</td>
<td>154</td>
</tr>
</tbody>
</table>

*Adjusted to the U.S. 1950 white population; cases per 100,000 population per year.

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**Table 3**

<table>
<thead>
<tr>
<th>Age group (yr)</th>
<th>Males No.</th>
<th>Rate</th>
<th>Females No.</th>
<th>Rate</th>
<th>Total No.</th>
<th>Rate</th>
</tr>
</thead>
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<tr>
<td>&lt;35</td>
<td>3</td>
<td>1.6</td>
<td>5</td>
<td>2.3</td>
<td>8</td>
<td>2.0</td>
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<tr>
<td>35-44</td>
<td>11</td>
<td>31.6</td>
<td>1</td>
<td>2.7</td>
<td>12</td>
<td>16.6</td>
</tr>
<tr>
<td>45-54</td>
<td>32</td>
<td>117.5</td>
<td>12</td>
<td>35.5</td>
<td>44</td>
<td>72.1</td>
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<tr>
<td>55-64</td>
<td>83</td>
<td>407.8</td>
<td>53</td>
<td>184.2</td>
<td>136</td>
<td>276.8</td>
</tr>
<tr>
<td>65-74</td>
<td>122</td>
<td>897.7</td>
<td>97</td>
<td>460.6</td>
<td>219</td>
<td>652.0</td>
</tr>
<tr>
<td>≥75</td>
<td>137</td>
<td>2,104.5</td>
<td>221</td>
<td>1,633.4</td>
<td>358</td>
<td>1,786.4</td>
</tr>
<tr>
<td>Total</td>
<td>388</td>
<td>133.9</td>
<td>389</td>
<td>110.2</td>
<td>777</td>
<td>120.9</td>
</tr>
</tbody>
</table>

*Cases per 100,000 population; rates based on estimated population July, 1962.
†Includes embolic infarction.
PREVALENCE
On January 1, 1960, there were 279 Rochester residents who were alive and had had a stroke. The corresponding numbers for January 1, 1965, and January 1, 1970, were 286 and 303, respectively (table 5). The rates were not significantly different for the last three dates on which prevalence was determined. On each date, about 0.4% of those 45 to 54 years old had had a stroke; this figure was about 1% for age 55 to 64 years, about 4% for age 65 to 74 years, and about 8% for those 75 years old and older.

STATUS OF SURVIVORS
Of persons who survived the first stroke and who were alive six months after the onset, only 4% required total care, 18% were capable of self-care, and 36% were working or were able to work (table 6). Ten percent were aphasic, but these also had other disabilities. Reflecting that mild strokes were also a part of the study, 29% of the survivors were functioning normally.

DEATH CERTIFICATES
Death certificates were obtained for all of the 672 persons who had had a stroke and died while a resident of Rochester during the years 1955 through 1969. Of those who died within one month after the stroke, 85.6% had some type of stroke mentioned as the underlying or an associated cause of death. However, of those who died more than one month after the stroke, only 45.6% had stroke noted on the death certificate (table 7).

SURVIVORSHIP
Among patients with cerebral thrombosis, 82% were alive 30 days after the onset of stroke (fig. 1). The one-month survivorship for cerebral embolus was 67%; for intracerebral hemorrhage, it was 16%; and for subarachnoid hemorrhage, it was 48% (fig. 1).

The probabilities of surviving each type of stroke for as long as 15 years was compared to the survival of a standard Minnesota population made up of persons the same age, sex, and race as the individual study populations (figs. 2, 3, 4, and 5).

CAUSE OF DEATH
Of patients who had had their first stroke in the study period and who had died prior to January 1, 1970,

The probabilities of surviving each type of stroke for as long as 15 years was compared to the survival of a standard Minnesota population made up of persons the same age, sex, and race as the individual study populations (figs. 2, 3, 4, and 5).

CAUSE OF DEATH
Of patients who had had their first stroke in the study period and who had died prior to January 1, 1970,

The probabilities of surviving each type of stroke for as long as 15 years was compared to the survival of a standard Minnesota population made up of persons the same age, sex, and race as the individual study populations (figs. 2, 3, 4, and 5).

CAUSE OF DEATH
Of patients who had had their first stroke in the study period and who had died prior to January 1, 1970,
about 38% died of the initial stroke, 10% died of a subsequent stroke, and 18% died of heart disease (table 8). This is essentially the same distribution as in the earlier Rochester study of stroke, 1945 through 1954, in which 41% died of the first stroke, 10% of a subsequent stroke, and 18% of heart disease.

**Recurrence of Stroke**

Of 694 patients who survived more than one month after the first stroke, 185 (27%) had recurrence of stroke prior to January 1, 1970. Prior to that date, 140 patients had had a single recurrence, 25 had two recurrences, five had three recurrences, and three had four recurrences. The distribution of second strokes by type was similar to that of the first stroke, with one exception—subarachnoid hemorrhage was underrepresented. There were only two instances of such hemorrhage compared to the expected 12 if the distribution were the same as that of the first strokes.

Among patients who survived the first stroke more than one month, 10% had a second stroke within one year and 20% had a second stroke within five years. Among the survivors of the first year, 5% had a recurrence in the second year; and among the survivors of the second year, about 5% had a recurrence in the third year.

**Discussion**

The population of Rochester, Minnesota, offers unique opportunities for the study of stroke because of the medical care readily available to the local population through the Mayo Clinic and its facilities and because the diagnostic indexing and record retrieval system makes the information available for study. In addition, the relative isolation from other communities makes it almost certain that patients with cerebrovascular disease are seen first within the community and that they are readily available for follow-up.

This study has attempted to identify all patients in the population of the community who had stroke during a period of 15 years and to determine, by complete follow-up, the course and survival of patients who have had strokes. All patients with cerebrovascular disease, including many with mild but definite stroke who may have been seen at home, in nursing homes, or on an outpatient basis, were included in the study. The study does not include cases of cerebral infarct found first at autopsy when there was no history of a clinical event of stroke.

**Comparison of the results of the previous Rochester stroke study** and the present study makes it possible to evaluate the long-term trend in incidence rates, prevalence rates, and survival for patients with cerebrovascular disease in the community.
From 1945 through 1954, the incidence rates for all strokes and for cerebral thrombosis were higher for men than for women of all except the oldest age groups, but the difference was not significant at any age. From 1955 through 1969, the rates for all strokes and for cerebral infarction were significantly higher for men than for women except in the youngest age group.

If 1945 data are not included, the rates for 1946 through 1949 are the same as for 1950 through 1954. After the first ten years of the study of stroke in Rochester (1945 through 1954), the average annual incidence rate for all strokes decreased in each succeeding five-year interval and reached 141 during the period 1965 through 1969 (fig. 6). The decrease in the rate is apparent for all strokes and for cerebral infarction due to all causes (fig. 7). The decrease in rate from the earliest to the latest five-year period is more apparent for women, there being a decrease of 32% for all strokes and of 28% for cerebral infarction. For men, the decrease in the rate during the 25-year period was 20% for all strokes and 12% for cerebral infarction (fig. 7). Since this decrease in incidence rates probably is not a reflection of changes in diagnostic pattern or in case ascertainment, it may reflect an effect of treatment in the population, such as the increasing use of antihypertensive medication.
Because the number of cases of cerebral hemorrhage and subarachnoid hemorrhage is relatively small, a comparison of the incidence rates of these two entities for various time intervals during the 25-year period is not as reliable. No significant change in the incidence rates for these entities can be demonstrated during the 25-year period.

The distribution of the types of stroke in the last 15 years is almost identical to that of the first ten years, if data on cerebral infarction from thrombosis and embolus are combined. In both studies, embolic infarction probably has been underestimated because of the requirement of the recognition of a source for embolus by the clinician at the time of the stroke.

Cerebral hemorrhage accounted for only about 10% of the strokes in the earlier study and in this one. This is considerably lower than the 58.9% that Wylie found using mortality statistics and is lower than the 36% reported in the population survey in Middlesex, Connecticut. The Framingham study reported that 4% of strokes were due to cerebral hemorrhage. As we have pointed out before, mortality statistics are unsatisfactory for determining the extent of strokes in a community and for determining the relative distribution of types of stroke.

The age-adjusted and sex-adjusted prevalence rate for stroke in the Rochester community was about 700 per 100,000 population on January 1 of 1960 and 1965, while the rate was 538 on January 1, 1955, and 559 on January 1, 1970. Because prevalence reflects the accumulation and survival to a given date of the cases that occurred during the previous period of study, it is affected by the length of time covered by the study. Thus prevalence on January 1, 1955, should include all surviving patients in the community who were diagnosed or observed during the previous ten years but, with some exceptions, does not include cases of stroke that occurred prior to 1945 since there was no special attempt to identify those. The prevalence rate on January 1, 1965, includes survival during a 20-year period, and the prevalence rate of January 1, 1970, includes survival during a 25-year period. Thus even if the incidence rates and survival have not changed throughout the 25 years, one would expect some increase in the prevalence rates for any date in the period 1955 through 1969 as compared to a date in the earlier ten-year period. The lack of difference in prevalence in 1960 and 1965 compared to 1955 suggests that the earlier rate did not include some long-term survivors from the earlier period. The lower prevalence rate in January, 1970, is apparently related to the decreasing incidence rates from 1955 to 1969 and is modified by modestly improved long-term survivorship during this period. A prevalence rate of 383 per 100,000 was estimated in the Hisayama study, based on the presence of neurological deficit at the time of first examination. The combined one-year incidence-prevalence rate for Middlesex County was 220 per 100,000. Nearly complete case ascertainment, the large number of milder strokes identified in the...
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Probability of survival after subarachnoid hemorrhage, compared to expected survival for Minnesota population of same age and sex distribution (life table for Minnesota, 1960).

For patients who had their first stroke in the last 15 years of the study, the distribution of causes of death is almost identical to that for patients who had their first stroke in the first ten years of the study. Also, the recurrence rate of stroke in the first ten years was similar to that in the last 15 years. The first-year recurrence rate was 10% in both periods. The five-year recurrence rate was 23% in the first ten years of the study and 20% in the last 15 years.

For cerebral thrombosis (infarction without known source for embolus), cerebral embolus (infarction with known embolic source), and

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**TABLE 8**


<table>
<thead>
<tr>
<th>Cause</th>
<th>Cerebral thrombosis</th>
<th>Cerebral embolism</th>
<th>Intracerebral hemorrhage</th>
<th>Subarachnoid hemorrhage</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial stroke</td>
<td>105</td>
<td>21</td>
<td>75</td>
<td>33</td>
<td>21</td>
<td>255</td>
</tr>
<tr>
<td>Subsequent stroke</td>
<td>51</td>
<td>9</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>54</td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>68</td>
</tr>
<tr>
<td>Cardiac failure</td>
<td>47</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>55</td>
</tr>
<tr>
<td>Respiratory tract disease</td>
<td>44</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>59</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Cancer</td>
<td>24</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>33</td>
</tr>
<tr>
<td>Other</td>
<td>40</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>53</td>
</tr>
<tr>
<td>Unknown</td>
<td>55</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>69</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>429</strong></td>
<td><strong>58</strong></td>
<td><strong>97</strong></td>
<td><strong>42</strong></td>
<td><strong>46</strong></td>
<td><strong>672</strong></td>
</tr>
</tbody>
</table>
subarachnoid hemorrhage, the yearly interval death rates are consistently higher than the mean life table rates for the persons left to be observed in that interval. Stated another way, survival for persons in each of these categories of stroke, relative to the expected survival, decreases throughout the study. The same is true for intracerebral hemorrhage, but the number of persons left to be observed after two years is too small to be considered.

For each category of stroke, when the ages of the survivors of each yearly interval are determined, and expected death rates for each interval are then calculated, these expected rates remain relatively constant. One would ordinarily expect the rates to increase sharply, because the patients are relatively old. This indicates that the older persons die disproportionately soon after the occurrence of stroke, and this trend continues throughout the observation period.

The time trend of survivorship for patients with cerebral infarction (including embolic infarction) is shown for one month, one year, and five years (fig. 8). The highest survivorship occurred in the five-year period 1955 through 1959, owing possibly to the disproportionate number of milder strokes during this period. During the 25-year period,
however, there has been a trend toward gradually increasing survivorship for cerebral infarction at each of these points in time after the occurrence of the stroke. This study has not identified the reason for this increased survivorship.

References
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