A DECLINE IN THE MORTALITY from cerebrovascular disease during the last several decades has been described in several reports. However, there are inherent difficulties in the interpretation of mortality data. Problems that can be identified include revisions in codes for cause of death, changes in terminology and patterns of diagnosis, low autopsy rates, and low accuracy of diagnosis, especially in differentiating various categories of cerebrovascular disease.

This study was undertaken to examine the trends in mortality from stroke in the United States and Rochester, Minnesota. In Rochester, virtually all residents receive their medical care at the Mayo Clinic and its associated hospitals or the Olmsted Medical Group and the Olmsted Community Hospital. The records of all of these facilities are linked for indexing and retrieval. This assures identification of practically all residents with serious medical problems, whether their conditions were diagnosed in the hospital or in one of the outpatient facilities or at autopsy. The community has long had a high degree of neurologic expertise, a high autopsy rate (>50%), and a relatively uniform assignment of cause of death. Virtually all death certificates, including those for deaths in which no autopsy is performed, are completed by Mayo Clinic pathologists.

Methods

All patients were identified who had a clinical or pathologic diagnosis of stroke at some time and died while residents of Rochester during the 30-year period 1945-1974. For the purpose of this study, the criteria for the diagnosis of stroke included (1) signs of focal neurologic deficit due to a vascular lesion of the central nervous system present for at least 24 hours and clinical characteristics to suggest that a stroke was the cause of the lesion or (2) a recent stroke documented at the time of death. Presence of any category of conditions was the cause of death. Whether different patterns of medical care affect the trends in stroke mortality has not been determined.

The trend in mortality rates for Rochester corresponds well with decreasing incidence rates and lack of change in case fatality rates previously reported.
Among these, 88% had been seen as patients at the Mayo Clinic, and the remainder were seen at the Olmsted Medical Group or the Olmsted Community Hospital. Of all deaths, 690 (46.6%) were coded to cerebrovascular disease rubrics of the ICD revision in effect at the time of death; 717 (48.4%) were coded to cerebrovascular disease rubrics when the death certificates were recoded according to the eighth revision (ICD 430-438). Among the 1,481 deaths, 51% had complete autopsies, including study of the brain. A review of clinical records revealed that 688 (46.5%) deaths could be attributed to a stroke.

Cardiovascular deaths, excluding cerebrovascular disease (ICD 390-429 and 440-458) accounted for 497 (33.6%) of the 1,481 deaths. Neoplasms accounted for 91 (6.1%) deaths.

The distribution of types of first stroke based on clinical information is noted in table 1. The table also shows the distribution of the types of any stroke that was the cause of death.

## Results

Among Rochester residents, 1,481 persons (654 males and 827 females) who had previously suffered some type of stroke died between 1945 and 1974. These include patients who died from their first stroke or anytime thereafter, regardless of cause of death. Among these, 88% had been seen as patients at the Mayo Clinic, and the remainder were seen at the Olmsted Medical Group or the Olmsted Community Hospital. Of all deaths, 690 (46.6%) were coded to cerebrovascular disease rubrics of the ICD revision in effect at the time of death; 717 (48.4%) were coded to cerebrovascular disease rubrics when the death certificates were recoded according to the eighth revision (ICD 430-438). Among the 1,481 deaths, 51% had complete autopsies, including study of the brain. A review of clinical records revealed that 688 (46.5%) deaths could be attributed to a stroke.

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## Trends in Rochester

Table 2 shows the 5-year average annual mortality rates for all strokes in Rochester. These data are based on the recoding of all death certificates to the eighth revision. The trends for males showed a decline of 68% between the first and last 5-year periods. There was a decline of 64% for females and 67% for the total population.

### United States and Minnesota Trends

Crude numbers of deaths for all strokes and the

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**Table 1** Distribution of Types of First Stroke and Types of Stroke Causing Death

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>ICD* code</th>
<th>Type of first stroke†</th>
<th>No.</th>
<th>%</th>
<th>Type of stroke causing death†</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cerebral thrombosis or embolus</td>
<td>432-434</td>
<td>1,116</td>
<td>75.4</td>
<td></td>
<td>341</td>
<td>47.6</td>
<td></td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>431</td>
<td>168</td>
<td>11.3</td>
<td></td>
<td>165</td>
<td>23.0</td>
<td></td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>430</td>
<td>85</td>
<td>5.7</td>
<td></td>
<td>69</td>
<td>9.6</td>
<td></td>
</tr>
<tr>
<td>Other/unknown</td>
<td>435-438</td>
<td>112</td>
<td>7.6</td>
<td></td>
<td>142</td>
<td>19.8</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1,481</td>
<td></td>
<td></td>
<td>717</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*International Classification of Disease.
†Based on clinical information.
‡Based on eighth revision coding of death certificates.

---

**Table 2** Five-Year Average Annual Mortality Rates* for All Strokes Comparing Rochester, MN, Minnesota, and United States White Populations

<table>
<thead>
<tr>
<th>Period</th>
<th>Rochester Male†</th>
<th>Female†</th>
<th>Total‡</th>
<th>Minnesota Male†</th>
<th>Female†</th>
<th>Total‡</th>
<th>US Male†</th>
<th>Female†</th>
<th>Total‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945-1949</td>
<td>104</td>
<td>79</td>
<td>91</td>
<td>108</td>
<td>107</td>
<td>108</td>
<td>105</td>
<td>100</td>
<td>103</td>
</tr>
<tr>
<td>1950-1954</td>
<td>74</td>
<td>101</td>
<td>92</td>
<td>124</td>
<td>116</td>
<td>120</td>
<td>115</td>
<td>106</td>
<td>110</td>
</tr>
<tr>
<td>1955-1959</td>
<td>61</td>
<td>61</td>
<td>61</td>
<td>125</td>
<td>112</td>
<td>118</td>
<td>114</td>
<td>103</td>
<td>108</td>
</tr>
<tr>
<td>1960-1964</td>
<td>69</td>
<td>62</td>
<td>65</td>
<td>117</td>
<td>104</td>
<td>110</td>
<td>107</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>1965-1969</td>
<td>60</td>
<td>43</td>
<td>50</td>
<td>108</td>
<td>94</td>
<td>101</td>
<td>101</td>
<td>87</td>
<td>94</td>
</tr>
<tr>
<td>1970-1974</td>
<td>33</td>
<td>29</td>
<td>30</td>
<td>89</td>
<td>78</td>
<td>83</td>
<td>95</td>
<td>84</td>
<td>89</td>
</tr>
</tbody>
</table>

*Per 100,000 population.
†Age-adjusted to 1960 US white population.
‡Age- and sex-adjusted to 1960 US white population.
Cerebral Infarction

The category of cerebral infarction includes all thrombotic and embolic strokes and occlusion of pre-cerebral arteries (ICD 432-434). The trends seen in the United States were not greatly influenced by revision changes, as evidenced by smooth transitions from one revision to another (fig. 2).

From 1945–1949 to 1960–1964 in the United States white population, there was an increase in the mortality rate due to cerebral infarction from 13 to 33 per 100,000, for an increase of greater than 150%. After 1964, there was a modest decline of 14%. However, from 1945–1949 to 1950–1954, the Rochester population had a small initial increase in mortality rate from cerebral infarction, followed by a progressive decline, with a net decrease of 61%. The eighth revision of the ICD was used to determine this diagnosis in Rochester for all years (fig. 2).

The trends in mortality rates in males and females in Rochester were similar, except that the males did not show the initial increase in rates prior to a decline to 16 per 100,000 per year. In females, there was a larger initial increase from 25 to 62 between the first and the second 5-year period, then a decline to 13 per 100,000 per year in 1970–1974.

Cerebral Hemorrhage

The trend of mortality from cerebral hemorrhage is difficult to follow because the revision changes, especially from the seventh to the eighth revisions, caused dramatic variations in the mortality rates. Prior to the sixth revision, which became effective in 1949, cerebral hemorrhage was not separated from subarachnoid hemorrhage so this analysis begins with 1950. There was a progressive decline from 1950 until 1968 when the eighth revision resulted in a dramatic redistribution of deaths out of the category of cerebral hemorrhage (ICD 431) (fig. 3). Cerebral hemorrhage in the Rochester population (eighth revision) declined sharply from 21 per 100,000 per year in 1950–1954 to 12 in 1955–1959. There was an increase in 1960–1964 to 17, then a smooth decline through 1970–1974, for a net decline of 77% (fig. 4). The eighth revision of the ICD was used to determine this diagnosis in Rochester in all of the years. The variation in the rates may be an artifact due to the relatively small numbers in each 5-year period; however, it corresponds to a similar trend in the incidence rates for intracerebral hemorrhage for the same time period in Rochester. The rates and trends for both sexes are similar to those seen for the total populations. There was also a large decline in the United States white and the Minnesota populations,

**Table 3. Change in Mortality Rates From All Strokes From 1945–1954 to 1965–1974**

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Population</th>
<th>Male (%) change</th>
<th>Female (%) change</th>
<th>Total (%) change</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;55</td>
<td>Rochester</td>
<td>-78</td>
<td>-6</td>
<td>-54</td>
</tr>
<tr>
<td></td>
<td>Minnesota</td>
<td>-38</td>
<td>-48</td>
<td>-43</td>
</tr>
<tr>
<td></td>
<td>United States White</td>
<td>-31</td>
<td>-35</td>
<td>-33</td>
</tr>
<tr>
<td>55–74</td>
<td>Rochester</td>
<td>-52</td>
<td>-67</td>
<td>-61</td>
</tr>
<tr>
<td></td>
<td>Minnesota</td>
<td>-26</td>
<td>-41</td>
<td>-34</td>
</tr>
<tr>
<td></td>
<td>United States White</td>
<td>-25</td>
<td>-38</td>
<td>-31</td>
</tr>
<tr>
<td>75+</td>
<td>Rochester</td>
<td>-32</td>
<td>-61</td>
<td>-54</td>
</tr>
<tr>
<td></td>
<td>Minnesota</td>
<td>-4</td>
<td>-5</td>
<td>-5</td>
</tr>
<tr>
<td></td>
<td>United States White</td>
<td>+4</td>
<td>+3</td>
<td>+3</td>
</tr>
</tbody>
</table>

*per 100,000 population

**Figure 1.** Five-year average annual mortality rates per 100,000 population, for all strokes, age- and sex-adjusted to 1960 United States white population. Compares United States white, Minnesota, and Rochester populations.

**Figure 2.** Five-year average annual mortality rates for cerebral infarction, comparing United States white and Rochester populations. Eighth revision of International Classification of Disease was used to determine diagnosis for Rochester for all years.
but these are misleading because of the large effect of the 1968 ICD revision change.

It is noteworthy that at all times the Rochester rates for cerebral hemorrhage were less than one-third those for the United States white population and Minnesota population. During 1950–1954, when the original codes were available on the death certificates, recoding to the eighth revision resulted in a decrease of 35% in the mortality rates for cerebral hemorrhage, again reflecting the impact of changing ICD codes on mortality data.

**Subarachnoid Hemorrhage**

The number of cases of subarachnoid hemorrhage in Rochester does not permit a detailed analysis, but some trends can be seen. The crude mortality rates in the United States white population increased 68% from 2.5 in 1950–1954 to 4.2 in 1970–1974, whereas there was an insignificant change in the rates for Rochester from 5.1 to 5.9 during the same period. The mortality rates for United States white and Rochester populations are compared in figure 5. The near doubling of the mortality rate in the United States white population may be due in part to increasing recognition during the time of these observations.

**Clinical Causes of Death as a Source of Mortality Data**

Clinical and autopsy records were used to determine rates that were not dependent on rules of coding, practices of assigning cause of death on the death certifi-
in the mortality data resulting from rule changes and personal interpretation of the rules.

Relative Distribution of Types of Stroke

The distribution of types of first stroke among all those who died in Rochester was similar to the incidence data of Matsumoto et al., Kannel et al., and Garraway et al. Cerebral infarcts, including embolic infarct, accounted for 75%, cerebral hemorrhage for 11%, subarachnoid hemorrhage for 6%, and others for 8%.

The differences in the distribution of first strokes among those who died from the stroke can be attributed to the different case fatality rates for each category. We have, for example, that 1:3.3. It was not until the 1970’s that the published vital statistics indicated that cerebral infarction outnumbered cerebral hemorrhage as a cause of death.

A dramatic change occurred in the category of cerebral hemorrhage in 1968 when the death certificate diagnosis of “CVA” was redistributed to the ICD rubric 436 “acute but ill-defined cerebrovascular disease” from ICD 431 “cerebral hemorrhage,” giving the result shown in Figure 3.

Discussion

This study identified 1,481 patients who died while residents of Rochester, Minnesota, between 1945 and 1974; all had previously suffered a stroke, according to clinical and autopsy records. Trends in mortality from stroke in Rochester were compared with trends in the United States and in Minnesota to determine whether data from Rochester (where there is a very high level of neurologic expertise, high autopsy rates, and involvement of the Mayo Clinic pathologists in completing virtually all death certificates) would be significantly different from national trends.

little difference was noted between the number of Rochester patients who were determined, by clinical and autopsy findings, to have died as a result of a stroke and the number of death certificates coded to a stroke cause either by the original code or the eighth revision.

Two points can be made from the comparison of temporal trends in Rochester with the United States white and the Minnesota populations. First, the actual mortality rates in Rochester were 12% lower than in the United States white population in 1945-1949 and 66% lower in 1970-1974. Rates noted by Soltero et al. (after the base year for age adjustment is considered) are similar to those noted for the United States in this study. The Rochester rates were lower than rates in Memphis and much lower than rates in other countries.

The reason for these differences can only be presumed. Geographic differences may account for some of the differences. Borhani investigated geographic differences in the United States and suggested that ethnic variations in disease as well as differences in the clinical management of arterial hypertension may be involved. This, however, can only be part of the answer. The nature of the community of Rochester allows for more accurate diagnosis and assignment of cause of death and thus provides high reliability in regard to the actual trends in mortality in this community.

This is further supported by the rates seen in the various categories of stroke where, in the Rochester population, cerebral infarction has accounted for a much larger proportion of total stroke deaths throughout the entire 30 years of study than has cerebral hemorrhage. This is now well established as being the actual case, but the United States Vital Statistics would give the opposite impression until recent years. In the earlier United States data (1950-1954), the ratio of infarction to hemorrhage was 1:3.3. It was not until the 1970’s that the published vital statistics indicated that cerebral infarction outnumbered cerebral hemorrhage as a cause of death.

A dramatic change occurred in the category of cerebral hemorrhage in 1968 when the death certificate diagnosis of “CVA” was redistributed to the ICD rubric 436 “acute but ill-defined cerebrovascular disease” from ICD 431 “cerebral hemorrhage,” giving the result shown in Figure 3.

A report from the National Center for Health Statistics showed a decrease of nearly 47% in rubric 431 “cerebral hemorrhage” as a result of the eighth revision, while more than 91% of the deaths coded to ICD 436 were formerly called cerebral hemorrhage. This shift made a much less dramatic impact on the Rochester data because fewer deaths were assigned the vague diagnosis of CVA.

The trends in age-specific mortality rates (table 3) indicate that, in the United States white and Minnesota populations, stroke was more often assigned as a cause of death in persons more than 75 years old than it was in the more controlled medical setting in Rochester.

Mortality rates derived from clinical and autopsy data (table 4) further support the accuracy of the trends determined from death certificates in Rochester, since both the rates and temporal trends correspond well.
Conclusion

The purpose of this study has been to demonstrate that uniform methods of diagnosis and assignment of cause of death result in high reliability in regard to the trends in mortality from stroke and various categories of stroke. It has been demonstrated that, in all categories of stroke except subarachnoid hemorrhage, the mortality rates in Rochester are lower and show a more rapid decline with the passage of time than do published Vital Statistics for the United States. This may be due partly to the effects of ICD revision changes and possibly to assignment of nonstroke deaths to stroke causes on the death certificate in the United States and Minnesota as a whole to a greater extent than in the community of Rochester. These observations indicate that the published vital statistics have significant pitfalls, and particularly so in the various categories of stroke. The differential between the rates for United States white and Rochester populations is greatest in the older age groups.

The information derived from the Rochester population provides a reliable representation of the trends in mortality from various categories of stroke because some of the inconsistencies of diagnosis, assignment of cause of death, and coding changes have been overcome. The decline in mortality rates for Rochester corresponds well with the decreasing incidence rates and lack of change in case fatality rate previously reported. These trends, however, may not be representative of all population groups in the United States in view of other ethnic, cultural, and geographic variables not considered in this study. Whether the medical care in Rochester is enough different from other population samples to affect stroke mortality has not been determined.

References

A comparison of trends in mortality from stroke in the United States and Rochester, Minnesota.

G L Anderson and J P Whisnant

Stroke. 1982;13:804-809
doi: 10.1161/01.STR.13.6.804

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