
Data From the Pawtucket Heart Health Program

Carol A. Derby, PhD; Kate L. Lapane, PhD; Henry A. Feldman, PhD; Richard A. Carleton, MD

Background and Purpose—Recent US data suggest there is a slowing of the decline in stroke mortality rates, accompanied by a constant morbidity rate. Hospital discharge rates for patients with stroke are influenced by numerous factors, and community-based surveillance data for validated cases are rare. Thus, reasons for the observed trends remain unclear. In the present study, we examined trends in validated cases of stroke for 1980 to 1991 in the combined populations of the Pawtucket Heart Health Program study communities and examined concomitant trends in classification, use of diagnostic procedures, and levels of risk factors.

Methods—Discharges for residents aged 35 to 74 years with International Classification of Diseases, Ninth Revision codes 431, 432, and 434 to 437 were identified through retrospective surveillance. A physician reviewed the medical records to validate case status.

Results—Between 1980 and 1991, 2269 discharges were confirmed as representing definite or probable strokes (59.5% of 3811 cases reviewed). The fatal stroke rate declined ($P < 0.005$) and the nonfatal stroke rate remained constant in both sexes. Case-fatality rates declined significantly ($P = 0.003$), and among strokes, the relative odds of death in 1990 versus 1980 was 0.50 (95% CI 0.34 to 0.72). The proportion of stroke discharges in which the patient received a CT scan or MRI increased 120%, and fewer strokes were classified as ill defined. Hypertension prevalence, treatment, and control rates remained constant in these populations.

Conclusions—Although causes for the observed trends remain unclear, results suggest that the decline in mortality rates is due to improved survival rates for patients with stroke. However, constant morbidity rates combined with constant rates of hypertension highlight the need for improved prevention to reduce the impact of stroke. (Stroke. 2000;31:875-881.)

Key Words: cerebrovascular disorders ■ epidemiology ■ morbidity ■ mortality

Mortality rates for cerebrovascular disease declined steadily in the United States for several decades beginning in the 1960s.1–4 However, national data and data from selected communities have suggested that the rate of decline in stroke mortality rates slowed during the latter half of the 1980s,1,2,5,6 and stroke remains the third leading cause of death among US adults.7 Although the decline in mortality rates has frequently been attributed to favorable trends in hypertension detection, treatment, and control,1 other studies have refuted this claim.3,8,9 Numerous other factors influence hospital discharge rates for stroke, including trends in incidence, in criteria for hospitalization, and in diagnostic and classification criteria. Thus, reasons for the observed secular trends remain unclear.

Community-based stroke surveillance data for confirmed cases of hospitalized stroke are rare. The morbidity and mortality surveillance system of the Pawtucket Heart Health Program (PHHP) provides a unique opportunity to examine trends in confirmed cases of hospitalized stroke in a well-defined community for which risk factor trends have been well documented. Therefore, the goals of this analysis were (1) to examine sex-specific trends in hospital discharge rates for confirmed stroke in the 2 southeastern New England communities included in the PHHP for the period of 1980 to 1991, (2) to examine concomitant trends in the composition of International Classification of Diseases, Ninth Revision (ICD-9) stroke discharge classification and in diagnostic procedures documented in the medical record, and (3) to examine simultaneous trends in population levels of cardiovascular risk factors.

Subjects and Methods

The PHHP

The PHHP was a community demonstration project that was conducted between 1980 and 1992 to evaluate whether a comprehensive...
TABLE 1. Demographic Characteristics of PHHP Study Communities, US Census Data 1980 and 1990

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<td>71,204</td>
<td>72,788</td>
<td>98,478</td>
<td>99,922</td>
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<td>Mean age, y</td>
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<td>33.6</td>
<td>37.1</td>
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<td>Female, %</td>
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<tr>
<td>White</td>
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<td>88.1</td>
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<td>5.5</td>
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<tr>
<td>Other</td>
<td>3.3</td>
<td>8.0</td>
<td></td>
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*Categories available for 1980 and 1990 differed slightly; 1990 data specify whites and blacks as Hispanic or non-Hispanic.

Potential cases were identified from hospital discharge tapes from the 7 hospitals in Rhode Island and Massachusetts that serve the study communities. Based on data from the state hospital associations, these hospitals were estimated to provide care for residents of the study communities. Eligible cases were residents of either study community, aged 35 to 74 years, who were discharged with an ICD-9 diagnosis code of 431 (intracerebral hemorrhage), 432 (other unspecified cerebral hemorrhage), 434 (occlusion of cerebral arteries) 435 (transient cerebral ischemia), 436 (acute ill-defined cerebrovascular disease), or 437 (other ill-defined cerebrovascular disease). A potential case was selected if 1 of these index codes was listed as either the primary or as 1 of the first 6 secondary ICD-9 discharge diagnoses.

For each eligible case, portions of the medical record were copied, including the discharge summary, CT or MRI scans, neurology consultations, and autopsy reports. The study physician then reviewed all available information to determine an outcome of definite stroke, probable stroke, no ascertainable stroke, or inadequate information. This classification was based on whether (1) the clinical description was consistent with a new localized neurological deficit involving hemispheres, brain stem, or the cerebellum and (2) whether there was evidence for intracerebral hemorrhage or without intraventricular extension and with or without subarachnoid extension. The following criteria were considered exclusions from the categories of definite or probable stroke: (1) exclusively subarachnoid hemorrhage, (2) cerebral infarction related to rheumatic mitral stenosis or infective endocarditis, (3) stroke due to the presence of prosthetic cardiac valves, (3) exclusively transient ischemic attack, or (4) evidence from the medical history that the hospitalization was for a previous stroke.

A confirmed case was classified as fatal if the patient died before discharge or if within 28 days of the admission date the patient either died out of hospital or died during a subsequent hospitalization. Out-of-hospital deaths were determined with the use of computerized data on all deaths, which were obtained from the state departments of health.

Population Estimates for Calculation of Event Rates

Midyear population estimates by sex, age, and city were prepared for each of the years 1980 to 1991 with the use of standard demographic techniques. The cohort-component method was used to take 1-year age groups created from the 1980 US Census and project them forward 1 year at a time with the use of national survival rates provided by the Bureau of the Census. Births were added for each year with information obtained from Vital Statistics reports for Rhode Island and Massachusetts. Finally, the population estimates were corrected for in-migration and out-migration with the use of estimates based on the 1980 Census data and corrected to the 1990 Census data.

Population Trends in Risk Factors

As part of the evaluation component of the PHHP, 6 biennial population random-sample household health surveys were conducted in each study community. Details of the survey design have been described in detail previously. For brief, survey participants were selected through the random selection of households and the application of methods adapted from those of Kish and Deming to randomly select 1 respondent between the ages of 18 and 64 from each household. Informed consent was obtained with a protocol approved by the Hospital Institutional Review Board on Human Research. Response rates were consistent across surveys, with an average of 86%. Each survey included a selection of respondents from each city, with a total of 15,249 surveys completed.

Demographic information, behavioral and physiologic cardiovascular risk factors, and current medication use were assessed by trained interviewers in the respondents’ homes. Current smoking was ascertained through self-report. This information was corroborated with serum thiocyanate measurements in samples from respondents to the first (n=1907) and second (n=437) surveys. With the use of a thiocyanate cut-point of 100 µmol/L to distinguish nonsmokers from smokers, the overall agreement with self-report was 88% (A.R. Assaf, unpublished observation, 1992). Self-reported medication use was validated with the interviewer’s visual inspection of medication bottles. Systolic and fifth-phase diastolic blood pressures were measured in the right arm with the respondent seated. The second of 2 measurements, taken ~20 minutes apart, was used.

Hypertension was defined as systolic blood pressure of ≥140 mm Hg, diastolic blood pressure of ≥90 mm Hg, or current treatment for hypertension. Respondents were classified as treated for hypertension if they responded “yes” to the question, “Are you taking any blood pressure pills?” and showed the interviewer a medication with this generally accepted indication, or if they indicated the use of a prescription diuretic in response to the question, “Are you taking a diuretic or water pill?” provided there was no other evidence of treatment for congestive heart failure.

Controlled hypertension was defined as current treatment with systolic blood pressure of <140 mm Hg and diastolic blood pressure of <90 mm Hg.

Statistical Methods

Results are presented as event rates per 10,000 population per year. The unit of analysis was a group defined by time, location, and demographics, and the total sample size for each specific event rate for the 12-year study was 48 (quarters)×2 (cities)×2 (sexes)×4 (age groups) 144 to 44, 45 to 54, 55 to 64, and 65 to 74 years)×768. An annualized rate for each quarter, city, sex, and age group was constructed by counting the number of recorded events, multiplying...
by 4 to obtain an annualized count, and dividing by a separately determined estimate of population for that period, in 10 000s.

In exploratory analysis, the demographic subgroups with higher event rates showed a proportionally higher fluctuation from quarter to quarter, similar to the variability of a Poisson-distributed random deviate. The rates were therefore square-root transformed for analysis to make residual variance homogeneous across subgroups. After analysis, adjusted mean rates were converted to natural units for presentation.

The transformed rates were analyzed with repeated measures ANCOVA with main effects for sex, city, age group, and season and all 2-factor interactions. Serial correlation across the 48 time points was modeled as first-order autoregressive. Interaction terms were kept in the model only if the P value for the term was statistically significant (<0.05). Time was included as a continuous variable that spanned the 12-year study.

Inferences that concerned the presence or absence of trends in the event rate were based on models in which time was treated as a continuous linear regression variable. The regression coefficient for time was estimated and tested for departure from zero (flat). A statistically significant positive or negative value was interpreted as an upward or a downward trend in the event rate. Variation of the significance or magnitude of the trend according to sex, age group, city, or season was tested with the use of interaction terms. No significant departures from linearity were detected.

Among cases of confirmed stroke, the presence of a temporal trend in case-fatality rates was assessed through the construction of logistic regression models in which the dependent variable was fatality and the main effect of interest was time (quarter), with adjustment for age, sex, and city.

Population trends in smoking and hypertension were assessed with a mixed-effects ANOVA model in which the primary independent variable was survey, coded as an ordinal variable. This survey term was modeled as first-order autoregressive. Interaction terms were kept in the model only if the P value for the term was statistically significant (<0.05). Time was included as a continuous variable that spanned the 12-year study.

Preliminary analyses indicated no evidence of differences in prevalence by city or for a significant difference in trends over time by city (interaction of city×time). Therefore, because city effects were not the outcomes of interest, results are presented for pooled data from the 2 cities.

The rate of fatal strokes declined significantly during the 1980s (P=0.004 for trend), with a similar pattern in men and women (P=0.99 for sex×time interaction) (Figure 1). Age-specific analyses (Table 3) showed that the trend was attributable to the age group of 65 to 74 years (P=0.007 for age×time interaction). Within this group, the average annual decline in fatal stroke was on the order of 10% per year in both sexes (P=0.0008).

The nonfatal stroke rate remained constant across the decade (P=0.85 for trend), with similar patterns for men and women (P=0.09 for sex×time interaction) (Figure 1). Analyses of fatal and nonfatal stroke trends based on ICD-9 discharge diagnosis were similar to those based on confirmed strokes.

## Results

### Morbidity and Mortality Trends

Medical record abstractions were completed for 96% of the 3975 eligible discharges. Of these, 59.5% met study criteria for a definite or probable stroke (Table 2). Half of all confirmed strokes were represented by ICD-9 discharge category 434 (occlusion of cerebral arteries), and 28% were represented by ICD-9 group 436 to 437 (acute and other ill-defined cerebrovascular diseases). Cases with a discharge classification of intracerebral or other unspecified hemorrhage (ICD-9 431 to 432) represented 9% of confirmed cases, and the remainder were represented by ICD-9 category 435 (transient cerebral ischemia).
Declining fatality rate paired with constant morbidity rate suggests a decrease in the case-fatality rate. Logistic regression analysis of confirmed strokes confirmed that the case-fatality rate declined significantly across the study period ($P < 0.003$ for trend). The age-, sex-, and city-adjusted relative odds of death (1990 versus 1980) was $0.50$ (95% CI 0.34 to 0.72).

**Trends in Diagnostic Technology and Classification**

Figure 2 displays the distribution of ICD-9 stroke discharge diagnoses between 1980 and 1990. During this period, the proportion of all stroke discharges classified as thromboembolic increased by $2$-fold, whereas the proportion classified as ill-defined stroke declined by $75\%$. In contrast, the proportions of stroke classified as transient ischemic attacks and as hemorrhagic remained fairly constant.

The use of CT or MRI as a diagnostic tool increased across the study period. As shown in Figure 3, the proportion of discharged stroke patients for whom CT scan or MRI records were included in the medical record and the proportion with documented neurology consults increased dramatically between 1980 and 1990; the increases were $120\%$ and $60\%$, respectively. The proportion of discharged stroke patients meeting study criteria for a definite or probable stroke increased by $20\%$.

**Population Trends in Risk Factors**

Figure 4 displays temporal trends in the prevalence of cardiovascular risk factors for the study communities during the 1980s. Between the periods 1981 to 1982 and 1992 to 1993, smoking declined in men from $45\%$ to $37\%$ ($P = 0.03$) and in women from $35\%$ to $31\%$ ($P = 0.50$). In contrast, the prevalence of hypertension, the proportion of hypertensive persons on treatment, and the proportion of treated persons who were controlled remained stable throughout the 1980s ($P > 0.20$).
Diagnosis and treatment efforts and of advances in neuroimaging and other diagnostic technologies are unclear.6,21,23 In particular, the forces driving these trends are attributable to improved survival rather than to declining incidence. Improved stroke survival rates may be the result of advances in diagnosis and treatment.25 The dramatic increase in the use of CT and MRI and the shift toward more specific classification of stroke in this population support this premise. Our observations are consistent with data from the National Hospital Discharge Survey that indicate a doubling of the proportion of stroke patients treated with diagnostic or surgical procedures between 1970 and 1990.26 Data from the Olmstead County, Minn, study show that the greatest improvement in short-term stroke survival rates occurred among patients with hemorrhagic stroke and occurred 5 to 21 days after onset. This suggests that earlier and improved detection and classification have facilitated more rapid and appropriate treatment of clinical sequelae.27 Finally, increases in the proportion of stroke patients admitted to intensive care units and of those receiving rehabilitative therapies have been observed.28 The management of stroke patients in a specialty stroke unit has been shown to reduce in-hospital mortality rates.29

It is also possible that improved stroke survival is an artifact of the rapid dissemination of CT and MRI technology since the 1970s. Increased detection of mild stroke could mask a true decline in morbidity rates and would result in apparent decreases in severity and case-fatality rates. In Rochester, Minn, Broderick et al2 demonstrated an increased incidence of stroke during the early 1980s concurrent with an increase in the use of CT. Similarly, National Hospital Discharge Survey data for the early 1980s show an increase in the discharge rate and a decrease in hospital case-fatality rates for stroke simultaneous with a tripling of the national rate of CT scans of the head.30,31 In the present study, there was a 20% increase in the proportion of strokes that were confirmed between 1980 and 1991. Despite the use of a consistent validation protocol across the study period, it is likely that the increased use of neuroimaging studies influenced the information available in the medical record and thus may have resulted in an increased proportion of cases validated over time. McGovern et al22 reported a similar pattern for the Minnesota Heart Survey for the period of 1970 to 1985. Thus, the influence of enhanced diagnostic information on the observed trends is an important consideration, although it is difficult to quantify the impact of trends in diagnostic technology on case validation.22,30,32

Although it is likely that the rapid increase in CT and MRI technology contributed to trends in stroke morbidity and mortality rates, data that directly assess the impact of advances in technology on surveillance data are limited. There is some evidence that improved detection of milder events does not explain the observed improvement in survival. In a recent population-based study, Barker and Mullooly28 compared the clinical manifestations of stroke cases with and without CT and found them to be similar, suggesting that CT

Discussion

During the period of 1980 to 1991 in the southeastern New England communities included in the PHHP, the rate of fatal stroke declined and the rate of nonfatal stroke remained constant. The age-adjusted case-fatality rate for hospitalized stroke declined throughout the decade, as would be expected given that the observed fatality rate declines were accompanied by stable morbidity rates. The patterns of stroke mortality and morbidity were similar for men and women, and overall, the decline in mortality rates was greatest among persons in the oldest age group (65 to 74 years).

These observations are consistent with national trends and with reports from other communities in which stroke mortality rates continued to decline and morbidity rates remained stable or even increased during the 1980s.1,2,5,6,20,21 We were able to confirm these observations with data for cases of stroke validated according to a standard medical record review. Although the patterns of stroke over time have been consistent across studies, the forces driving these trends are complex and remain a topic of debate.3,6,8,21,22 In particular, the relative contributions of primary and secondary prevention efforts and of advances in neuroimaging and other diagnostic technologies are unclear.6,21,23

Several reports have argued that declining stroke mortality rates are attributable to improved survival rates rather than to decreased morbidity rates.6,20,21,23,24 In the present study, the declining rate of fatal stroke concurrent with a constant nonfatal stroke rate is consistent with this hypothesis. However, because incidence data were not available, this hypothesis could not be directly tested. The few studies for which incidence data are available support the role of improved survival in the overall mortality rate decline, showing that the occurrence of new strokes remained unchanged or increased slightly during the 1980s.7,20 Population-based studies in North Carolina24 and Minnesota6,23 have also suggested that a substantial portion of the decline in the stroke mortality rate is attributable to improved survival rather than to declining incidence.
had not led to the diagnosis of mild strokes that would otherwise have been undetected. Similarly, data from the Minnesota Stroke Survey show improved survival rates even among subgroups of patients with notable deficits detectable without neuroimaging studies. This study also showed that survival rates improved even during the late 1980s, when neuroimaging studies were already in widespread use.

Improved survival rates for stroke could also be the result of a shift in the natural history toward reduced severity. Although indices of severity were not available in this study, observations from other communities have suggested decreased severity in patients hospitalized for stroke during the 1980s. A significant decline in the severity of neurological deficits resulting from stroke, accompanied by a reduction in the proportion of patients who were unconscious at the time of admission, was observed in the Framingham study population. Similarly, Barker and Mullooly found that among elderly enrollees in a large health maintenance organization population, the proportion of stroke patients with coma declined, and the proportion of stroke patients with speech or visual decrements increased between 1967 and 1985.

Whether secular trends in population risk factor levels, particularly hypertension, have contributed substantially to observed declines in stroke mortality rates has been debated. Flat or increasing incidence rates are not consistent with the reductions in stroke incidence predicted based on results from clinical trials of blood pressure reduction. In Rochester, Minn, the incidence of stroke stabilized or increased slightly simultaneously with improved rates of hypertension control. Similarly, stroke incidence in the Framingham cohort remained stable despite improvements in population levels of hypertension control, serum cholesterol, and smoking. However, others have speculated that improvements in hypertension control have influenced mortality trends by reducing the severity of incident events. Barker and Mullooly hypothesized that this influence would be manifest as a shift in hypertension-related strokes from massive hemorrhagic strokes to milder hemorrhagic strokes or an increase in thrombotic strokes.

Few studies have reported age-specific trends in validated stroke morbidity and mortality rates. The observation of the greatest decline in fatal stroke occurring in the oldest age group is similar to results from Rochester, Minn, where secular trends in stroke were most pronounced in the oldest age group. Data from the Minnesota Heart Survey show that stroke mortality rates plateaued between 1985 and 1990 and that this was most evident in the age groups of 30 to 49 and 70 to 74 years. It is likely that the strongest trends are observed in the oldest groups due to the increasing event rates with age and due to the rare number of events at young ages.

In the present study, the validation protocol did not discriminate among different levels of severity. We did observe a shift in ICD-9 classification for strokes such that the proportion classified as thrombotic increased, the proportion classified as ill defined decreased, and the proportion classified as hemorrhagic remained constant. However, this shift occurred during a period when the prevalence of hypertension and the proportion of hypertensives who were treated and controlled did not improve. Thus, the shift in stroke subtypes may be attributable more to the concomitant trends in the use of neuroimaging studies and neurology consults than to secular trends in cardiovascular risk factors.

This conclusion is supported by data from the National Hospital Discharge Survey that show a similar pattern of declining rates of stroke classified as ill defined and an increase in the rates for the more specific categories. It is important to note that we were not able to identify whether cases represented first occurrences of stroke. Thus, inferences regarding incidence trends are not possible and depend on the extent to which cases represent recurrent stroke. Declining incidence may be masked if improved survival leads to increasing prevalence of previous stroke and an increasing proportion of repeat stroke events. Repeat stroke events within the same calendar year were uncommon, representing only 8% of total cases. This is similar to previous studies that have reported a yearly recurrent stroke attack rate of <10%. We had no way of estimating the proportion of cases that represent recurrence in patients with a history of stroke years earlier.

In summary, these observations, which are based on cases validated according to a standard medical record review, show that stroke mortality rates in the PHHP communities declined during the 1980s, whereas morbidity rates remained flat. Whether the observed trends were due to primary or secondary prevention or to other forces, such as trends in diagnostic testing or in reimbursement strategies, remains a topic of debate. Continuing surveillance is needed, and there is a need for additional data that could directly assess the impact of sociodemographic forces, treatment advances, trends in diagnostic technology, and trends in population levels of risk factors on the patterns of stroke morbidity and mortality rates. Regardless of the relative contributions of these factors, the constant rate of morbidity paired with the lack of improvement in hypertension treatment and control highlights the need for improved efforts to control hypertension in the population. This is particularly true when these observations are combined with observations from other studies that show a lack of improvement in blood pressure control, flat or increasing rates of incidence, and a slowing of the rate of decline in mortality compared with prior decades.

**Acknowledgments**

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**References**


Trends in Validated Cases of Fatal and Nonfatal Stroke, Stroke Classification, and Risk Factors in Southeastern New England, 1980 to 1991: Data From the Pawtucket Heart Health Program

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