Life Expectancies Among Survivors of Acute Cerebrovascular Disease

Harald Hannerz, Licentiate; Martin Lindhardt Nielsen, MD

Background and Purpose—Stroke survivors represent a large group of persons for whom age-differentiated life expectancy tables do not exist. Such tables are vital for many purposes. The aim of the present study was to estimate age- and sex-specific life expectancies among individuals who have survived the acute phase (1 month) of a cerebrovascular disease (CVD).

Methods—All patients who were registered with the Swedish National Hospital Discharge Registry with an admission for CVD (ICD codes 430 to 438) between January 1, 1989, and November 30, 1993, and were alive at the end of 1993 (N=103,591) were followed for mortality rates in 1994. The same was done for 1983. Actuarial analyses were used to convert death rates into life expectancies.

Results—Life expectancy among CVD survivors increased with time (1983 versus 1994): 22.9% for men (95% CI 18.3% to 27.6%) and 12.9% for women (95% CI 9.1% to 16.6%). The life expectancy ratio in 1983 between CVD survivors and the general population was 0.571 (95% CI 0.533 to 0.590) for men and 0.578 (95% CI 0.562 to 0.592) for women. In 1994, the corresponding ratios were 0.641 (95% CI 0.629 to 0.654) and 0.611 (95% CI 0.601 to 0.622). The life expectancy ratios between female and male survivors were 1.28 (95% CI 1.23 to 1.34) in 1983 and 1.18 (95% CI 1.15 to 1.21) in 1994. The prognosis for survivors who experienced occlusion and stenosis of the precerebral arteries was better than that for survivors of an intracerebral hemorrhage (P=4.4E-4) or occlusion of cerebral arteries (P=3.8E-8).

Conclusions—Although the prognosis has improved for all ages, stroke survivors still constitute a large group of persons with a low life expectancy compared with the general population. (Stroke. 2001;32:1739-1744.)

Key Words: data analysis, statistical • prognosis • registries • stroke outcome • survival

To enhance the knowledge of how various types of health problems affect an individual’s life expectancy, researchers in public health, the national economy, the insurance industry, and other arenas have long realized that in addition to life tables for the general population, there is a need for tables that reflect mortality rates in various subgroups of the population. Life expectancy tables, which present the number of years expected to live, have been provided for survivors of acute myocardial infarction1,2 and persons with mental disorders.3,4 Because of the size of these groups and the impact that their survival development has on the mortality rates for the nation at large, these tables have been deemed vital not only for planning purposes but also for evaluation of treatment results.

Another interesting subgroup would be persons who have survived the acute phase of a cerebrovascular disease (CVD). In the United States alone, there are >3 million survivors of stroke, who collectively pose a formidable rehabilitation task.5 It has also been stated that survival is the most fundamental measure of the outcome of stroke6 and that, besides improving quality of life, prolongation of life is one of the chief goals of the rehabilitation process.7 Life expectancy tables for stroke survivors are needed to monitor this goal and are vital for planning purposes.

The aim of the present study was, first, to estimate age- and sex-specific life expectancies among individuals in Sweden who have survived the acute phase (1 month) of a CVD. The second aim to determine whether the survival potential among CVD survivors has changed over time (1983 versus 1994). A third aim was to determine whether the survival potential among CVD survivors depends on the type of CVD that was experienced.

The tables are based on a follow-up of >100 000 cases and are, to our knowledge, the first life expectancy tables that include the stroke survivors of an entire country.

Methods

The Hospital Discharge Registry (HDR) is a Swedish national register. It has been in existence since 1964 and can be used for research as well as administrative planning purposes. At the start in 1964, only 6 of 26 Swedish hospital regions reported to the registry. Gradually more hospitals joined, and since 1987, the register contains information on all hospital discharges from all public hospitals in Sweden.8

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The individuals examined for death in 1983 consisted of all persons registered with the HDR during the period of 1978 to 1982 whose records fulfilled the following criteria: (1) ≥1 of the discharge diagnoses was in the ICD-8 code 430 to 438 (CVD) grouping, (2) no admittance for ICD-8 codes 430 to 438 diagnoses in December 1982, (3) a valid Swedish personal identification number, and (4) alive on January 1, 1983.

The group examined for death in 1994 was defined in the same way but with the use of ICD-9 codes instead of ICD-8 codes and for the period of 1989 to 1993 instead of 1978 to 1982. The personal identification numbers ascertained that no person was counted more than once in each analysis.

It has been shown that the validity among primary diagnoses has a tendency to be higher than it is among secondary diagnoses. This favors the idea of only regarding the primary diagnosis in the analysis. The Swedish official instructions to the coders as to what diagnosis should be the primary diagnosis are, however, quite unclear. If, for example, a person who experiences a stroke also falls and fractures the femoral neck before arriving at an emergency hospital, then either of the 2 diagnoses can be put as the primary diagnosis, depending on how the instructions are interpreted. Hence, if an individual has >1 disease, the primary diagnosis depends on conventions that may vary from place to place and time to time. In the present study, we did not analyze conditions associated with the acute phase of the disease but were merely interested in finding people who had experienced CVD sometime in the past. In this context, we thought it was appropriate to include all patients who were registered with a CVD regardless of its position in the list of discharge diagnoses.

Patients who were not permanent residents of Sweden, such as refugees waiting for asylum, would not have a standard identification number and therefore were excluded from the study on the basis of the given conditions. This condition was important because any subsequent deaths of such persons would have been missed in the follow-up. Information on death was obtained by matching hospital discharge records with records in the Cause of Death Registry, which contains the deaths of all permanent residents of Sweden. The coverage of the register is good; only ~0.45% of deaths are missing. The social security system of Sweden, with free health care and a guaranteed minimum income that is far higher than what would be provided by social services in most other countries, would be a strong reason for persons with chronic health impairments to remain in the country. Moreover, to immigrate to other countries, a person would normally have to be a refugee or a highly attractive person on the labor market. These conditions indicate that the probability of emigration among the Swedish patient populations would be low. Even long-term register-based follow-up studies of such populations are therefore traditionally performed without recourse to national migration registers. Hence, we did not consider it necessary to include migration data in the analyses.

The procedure used to obtain life expectancy estimates is given in Technical Details.

Likelihood ratio tests were used to check for survival differences between subtypes of CVD in the 1994 sample. At the end of the 1980s, ~40% of all acute strokes were still diagnosed as unspecified CVD (ICD-9 code 436). Although the university hospitals had a high degree of specification, some hospitals registered an unspecified diagnosis for >70% of their patients. It would have been interesting to study single stroke diagnoses in the 1983 sample and it would have been desirable to exclude some of the diagnoses, such as ICD-8/9 code 435 (TIA), from the analyses. It is, however, well known that validity has a tendency to decline as the level of detail increases, and because of the high proportion of unspecified diagnoses, we did not have enough faith in the validity of single diagnoses in the early period to study anything other than the total group of CVDs.

As a summarizing index in survival comparisons between groups, we used age-standardized life expectancy ratios. For the standard population, we used all persons alive on January 1, 1994, who had been hospitalized with ICD-9 code 431 (intracerebral hemorrhage), 433 (occlusion and stenosis of precerebral arteries), or 436 (acute CVD not otherwise specified) during the period of 1989 to 1993. A graphic description of this population is given in Figure 1.

**Life Expectancy Ratios**

The following life expectancy ratios were calculated: (1) female CVD survivors in relation to male CVD survivors by calendar year, (2) CVD survivors in relation to the general population by sex and calendar year, and (3) CVD survivors in 1994 in relation to CVD survivors in 1983 by sex.

The numbers of persons at risk and median ages for the different study groups are given in Table 1. The large discrepancy in the number of cases in 1983 and 1994 is explained mainly by the fact that reporting to the HDR was voluntary before 1987. Slightly more than half of all Swedish inpatients were covered in that time period. After 1987, all inpatients of every public hospital in Sweden were included in the HDR.

**Results**

**Age-Standardized Life Expectancy Ratios**

Life expectancy among CVD survivors increased with time (1983 versus 1994): 22.9% for men (95% CI 18.3% to 27.6%) and 12.9% for women (95% CI 9.1% to 16.6%). The increase in life expectancy was greater among CVD survivors than it was in the general population. The life expectancy ratio between these groups in 1983 was 0.571 (95% CI 0.533 to 0.590) for men and 0.578 (95% CI 0.562 to 0.592) for women. In 1994, the corresponding ratio was 0.641 (95% CI 0.629 to 0.654) for men and 0.611 (95% CI 0.601 to 0.622) for women.

Female CVD survivors live longer than do male CVD survivors, but the difference between the sexes decreased with time. The age-standardized life expectancy ratio be-

**TABLE 1. Number of Persons at Risk and Median Ages in the Study Populations**

<table>
<thead>
<tr>
<th>Diagnosis (ICD Code)</th>
<th>Year</th>
<th>n</th>
<th>Median Age, y</th>
<th>n</th>
<th>Median Age, y</th>
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<td>430-438</td>
<td>1983</td>
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<td>21,653</td>
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<td>50,545</td>
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<tr>
<td>431, 433, 434, 436</td>
<td>1994</td>
<td>32,832</td>
<td>73</td>
<td>29,662</td>
<td>78</td>
</tr>
<tr>
<td>431</td>
<td>1994</td>
<td>32,58</td>
<td>69</td>
<td>28,31</td>
<td>73</td>
</tr>
<tr>
<td>433</td>
<td>1994</td>
<td>15,74</td>
<td>68</td>
<td>873</td>
<td>70</td>
</tr>
<tr>
<td>434</td>
<td>1994</td>
<td>19,466</td>
<td>73</td>
<td>16,756</td>
<td>77</td>
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</table>
between women and men was 1.28 (95% CI 1.23 to 1.34) in 1983 and 1.18 (95% CI 1.15 to 1.21) in 1994.

Life Tables

Age-specific life expectancies in the various study populations are given in Tables 2 and 3.

Years of Lost Life

By subtracting life expectancy in a study population from life expectancy in the general population, we obtained the measure of years of lost life.

CVD survivors lost more years of remaining life in 1983 than they did in 1994, which means that the increase in life expectancy was greater among CVD survivors than it was in the general population (Figure 2).

Even though female CVD survivors live longer than male CVD survivors, they will lose more years of remaining life than the men (Figure 3). The difference between men and women in life expectancy is, in other words, greater in the general population than it is among CVD survivors.

The life expectancy among survivors of occlusion and stenosis of precerebral arteries (ICD-9 code 433) was greater than it was among survivors of intracerebral hemorrhage \((P=4.4\times10^{-4})\) and occlusion of cerebral arteries \((P=3.8\times10^{-8})\).

The survival difference between the latter 2 groups is not statistically significant \((P=0.054)\). A graphic description is given in Figure 3.

Discussion

The present study indicates that the survival prognosis among persons who have survived the acute phase of CVD, according to records in the HDR, was better in 1994 than it was in 1983. The study also indicates that the differences in life expectancy between CVD survivors, identified by the HDR, and the general population are far from negligible and that they were higher in 1983 than they were in 1994. Despite a large difference in early mortality rates, no significant difference was found between life expectancies for survivors of cerebral hemorrhage and infarction due to intracerebral occlusion. The life expectancy was, however, significantly better in survivors of precerebral occlusion and stenosis.

In estimating life expectancies in a population, there are 2 kinds of survival models from which to choose: select models

<table>
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<tr>
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<td>2.4</td>
<td>2.8</td>
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### Table 2. Expectation of Remaining Life According to Periodic Mortality Rates in 1983 and 1994

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<th>Current Age, y</th>
<th>Men, in the General Population, y</th>
<th>Women, in the General Population, y</th>
<th>CVD Survivors, y</th>
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<tr>
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<td>3.2</td>
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### Table 3. Expectation of Remaining Life Among CVD Survivors According to Periodic Mortality Rates in 1994

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and aggregated models. A select model considers not only the ages of the concerned individuals but also how long time the individuals have been part of the study population. An aggregated model considers only the age factor. In the present study, we used an aggregated model; we have, in other words, assumed that the age-specific life expectancy is independent of the time passed since the individual first experienced a CVD. The choice of the aggregated model was not only a matter of simplification. It was a forced choice, because information regarding exact time points of individuals’ first contact with the disease was unavailable. We believe, however, that any bias from not working with a select model would be small in comparison with the potential bias inherent in the time-honored assumption that future mortality rates will be the same as “present” mortality rates, which is the foundation of all life expectancy estimates constructed from periodic mortality rates. The mean life expectancy in the general population of Sweden has increased rapidly during the past decades. Because the survival prognosis among CVD survivors has increased even more rapidly, it is easily realized that if this trend continues, the mean lengths of remaining life among CVD survivors today will be considerably longer than the estimates given in the life table of 1994. To ascertain that an aggregated model would not be too unrealistic, we estimated death in 1994 among stroke survivors, as a function of the calendar year of first admission during the sampling period (1989 to 1993). With patients who were admitted in 1989 as the base for comparison, the age- and sex-standardized ORs were 0.94 (95% CI 0.86 to 1.02) for 1990, 0.94 (95% CI 0.87 to 1.02) for 1991, 0.89 (95% CI 0.82 to 0.96) for 1992, and 0.97 (95% CI 0.90 to 1.05) for 1993.

In a US stroke study, it was reported that the severity of illness among patients diagnosed by CT did not differ from that of patients whose diagnoses were based only on symptoms. This gives us some hope that our results would not be too distorted by changes in diagnostic resources and procedures. It is, however, possible that the increased life expectancy observed during the 11-year period is not only due to the improvement in care. Because of more widespread availability of CT scanning and MRI, the diagnostic accuracy has changed over time: less severe strokes are now identified, and this probably contributes to the improved survival. Minor strokes that were not recognized during the first period are now clearly identified as stroke. Severity of illness may also have changed for other reasons. Indications for hospitalization may also have changed with time. To assume that the time period comparison was done on equivalent groups may therefore not be fully realistic. Another potential bias arises from the fact that the register covered only slightly more than half of the population in the first period. A natural question is whether the hospitals that participated in the early period differ from those that did not. To shed some light on this issue, we compared case-fatality rates (death within 1 month after admission with 1 of the ICD-9 codes 431, 433, 434, and 436) in 1992 with those in 1995. The hospitals that did not participate in the early period had an average case-fatality rate of 16.4%, whereas the average for the other hospitals was 15.6%. Because the case-fatality rate at individual hospitals ranged between 9.5% and 31.5%, the difference between participants and nonparticipants must be regarded as quite small. We also calculated life expectancies in 1994 of the survivors from hospitals that participated in the early period. The life expectancy estimates associated with the hospitals

![Figure 3. Expected years of lost life (YLL) for CVD survivors by age, sex, calendar year, and type of CVD (ICD-9 code).](image-url)
that participated were, on the average, only 0.5% higher than those obtained when all hospitals were included.

Regarding diagnostic errors among stroke patients, false-positive diagnoses seem to be considerably more common than false-negative diagnoses. An example is given by a diagnosis validation study in northern Sweden that found 32% of the stroke diagnoses were falsely positive and only 2% were falsely negative. The material used in the present survival study contained almost 150 000 observations. It is reasonable to believe that a considerable amount of these observations consisted of falsely positive CVD diagnoses. A natural question is what the result of the calendar time comparison would have been if all concerned medical records had been reviewed and only observations with verified CVD had been included in the study.

Researchers in Minnesota reported that although 5-year survival rates among patients with verified stroke increased significantly between 1970 and 1985, no increase was found among the patients with unverified stroke. If the same phenomenon is true for the patients followed in the present study, it would mean that the estimated increase in life expectancy would have been greater if we had included only patients with verified CVD.

Long-term survival among stroke patients has been reported to increase with time in a series of studies, and a number of possible explanations for this trend have been offered. In a stroke study in Söderhamn, Sweden, it was estimated that 3-year survival rates had increased 16% between the time periods of 1975 to 1979 and 1983 to 1987. The increased survival was assumed to be the effect of fewer fatal complications rather than a reduced risk for recurrent stroke.

According to the Minnesota Heart Survey, 5-year survival rates among stroke patients increased significantly between 1970 and 1985 (OR 0.72, 95% CI 0.54 to 0.96). A decrease in severity of illness and improved medical care were proposed as possible explanations.

In a survival study in north Sweden, the estimated odds for death within 1 year among patients who had survived the first 28 days of the disease decreased 27% among men and 30% among women during the period of 1985 to 1994. Similar improvements were found in 3- and 5-year survival rates. According to the authors, known prognostic confounders could not explain the findings, and it was proposed that the establishment of stroke units might have contributed to the increased survival.

The last mentioned hypothesis is supported by a Norwegian randomized study, from which it was concluded that stroke units do increase survival and that this effect remains for at least 18 months of observation.

Several other studies have also demonstrated increased survival with improved care of stroke patients, and it is now generally accepted that stroke units save many lives. When early death is decreased by such measures, an increasing number of stroke survivors live in countries with aging populations and high incidences of stroke. Although the late mortality rates have also been reduced, it is still considerably higher than in the general population, and this highlights the need for secondary prevention, even among the oldest patients. Because most risk factors are common with other major diseases of the same age groups, like myocardial infarction, diabetes, and cancer, synergy in prevention should be a realistic possibility.

Technical Details
To calculate and compare life expectancies, some kind of mathematical assumption about death distributions must be made. In the estimation of life expectancies, it was assumed that the mortality rates \( DF(x)[1−F(x)] \) and the conditional cumulative distribution functions \( [F(x+t)−F(x)]/[1−F(x)] \) could be based on equations 1 and 2 for women and equations 3 to 5 for men. For studies of the kind conducted in the present work, the following equations have been shown to be beneficial in terms of power as well as in goodness-of-fit.

\[
G(x) = \int g(x)dx = a_0 \frac{a_1}{x} + \frac{a_2}{2} x^2 + \frac{a_3}{c} e^{cx}
\]

\[
F(x) = \frac{e^{G(x)}}{1+e^{G(x)}}
\]

\[
F(x) = \alpha F_1(x) + (1−\alpha) F_2(x) = \alpha \frac{e^{G_1(x)}}{1+e^{G_1(x)}} + (1−\alpha) \frac{e^{G_2(x)}}{1+e^{G_2(x)}}
\]

\[
G_1(x) = a_0 \frac{a_1}{x} + \frac{a_2}{2} x^2 + \frac{a_3}{c} e^{cx}
\]

\[
G_2(x) = a_4 \frac{a_1}{x} + \frac{a_2}{2} x^2 + \frac{a_3}{c} e^{cx}
\]

For each of the studied populations, the parameters \( a_0, a_2, \) and \( a_4 \) were assessed through the maximum likelihood method. The remaining parameters were treated as deterministic and were given the calendar year– and sex-specific values obtained in the general population.

The variance of the estimations was obtained through inversion of Fisher’s information matrix. The probability values for the various hypotheses were based on likelihood ratio tests. Age-specific life expectancies, \( e_s \), were calculated through numerical solution of the following integral.

\[
e_s = \int_0^{\infty} \frac{1-F(x+t)}{1-F(x)} dt
\]

The age-standardized life expectancy ratio \( K_{ij} \) between populations \( i \) and \( j \) was obtained with the following equation:

\[
K_{ij} = \sum \frac{v_i e_{i,x}}{e_{j,x}}
\]

where \( e_{i,x} \) is the life expectancy for an \( x \)-year-old subject in population \( i \), \( e_{j,x} \) is the corresponding expectancy for population \( j \), and \( v_i \) is the proportion of \( x \)-year-old subjects in the standard population.

The variance in the \( K_{ij} \) estimates was obtained through the propagation of error formulas.
Acknowledgment
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Harald Hannerz and Martin Lindhardt Nielsen

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