SPINAL CORD INJURY

Clinical Outcomes from the Model Systems

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Long-Term Survival and Causes of Death

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INTRODUCTION

During the past 50 years, both acute and long-term survival rates for persons with SCI have improved dramatically.[1–16] In fact, although the prognosis for some persons (particularly those injured later in life who sustain neurologically complete tetraplegia) remains relatively poor, the life expectancy of others (e.g., persons with neurologically incomplete motor functional injuries and normal bladder function who survive the initial effects of the injury) now approaches normal. For most individuals with SCI, however, life expectancy remains somewhat below normal.[15]

Mortality rates are significantly higher during the first year after injury than during subsequent years, particularly for more severely injured individuals.[6,12,15,17–20] Not surprisingly, the most significant prognostic factors related to survival are age and measures of injury severity such as neurologic level, degree of injury completeness, and ventilator dependency.[5,12–16,20–24] Given comparable age and injury severity, females and whites have slightly higher survival rates than males and nonwhites, but the difference is not as great as it would be in the absence of SCI.[15] Undoubtedly, the long-term quality of care received by persons with SCI as well as many psychosocial factors are also important determinants of survival, but these have received relatively little attention.[25,26]

Until recently, renal failure and other urinary tract complications were reported to be the leading causes of death among persons with SCI.[13,27–31] This led many clinicians and investigators to focus their attention and research efforts on management of the neurogenic bladder and prevention of renal failure. As a result, enormous progress has been made toward reducing urinary tract–related morbidity and mortality. Studies conducted more recently suggest that respiratory system complications, particularly pneumonia, have surpassed urinary tract

complications as the leading underlying cause of both short- and long-term deaths among persons with tetraplegia.[8,9,22,32,33] Septicemia, suicide (particularly during the first several years), heart disease, and cancer are now the leading causes of death among persons with paraplegia.[8,16,24,32–36] Pulmonary emboli are also a leading cause of death early after SCI regardless of injury level.[32,33] Nonetheless, multiple inter-related causes play a role in many deaths, and although urinary tract complications are no longer among the leading underlying causes of death, they may still be a secondary or contributing cause, such as septicemia and, therefore, cannot be ignored.[32,33]

Historically, the Model Systems have placed a high priority on acquiring complete and accurate mortality information that has been an integral part of the National Database since its inception in 1973. This information includes the date of death, the primary (or underlying) cause of death, and up to four contributing causes of death. Causes are reported using ICD9CM codes after thorough review of all pertinent available records including hospital discharge summaries, death certificates, and autopsy reports. As a measure of the quality of cause of death information, a separate variable documents whether the reported cause was confirmed by autopsy.

Since collection of follow-up data is often difficult, the mortality information contained in the National Database is somewhat incomplete. As discussed in previous chapters, many individuals are ultimately lost to follow-up for a variety of reasons. Therefore, because of the high priority the Model Systems have placed on acquiring complete and accurate mortality data, considerable resources were expended to conduct periodic multisystem collaborative studies to supplement information contained in the National Database.[14,15,32,33] For these studies, each Model System made a special effort to identify the location of all former patients. Additional persons with traumatic SCI who did not meet the rigorous eligibility criteria for National Database inclusion but who were nonetheless injured since 1973, treated within 1 year of injury, and who survived at least 24 hours were also enrolled. The support of the Social Security Administration was enlisted to assist in identifying the survival status of persons who were otherwise lost to follow-up by searching its Master Beneficiary Record and Summary Earnings Record files for information on persons for whom benefit claims were submitted or for whom benefits were terminated because of death. By testing the accuracy of the Social Security Administration data with persons from the National Database whose survival status was already known, sensitivity (the ability to correctly identify people who were deceased) was found to be 92.4% and specificity (the ability to correctly identify people who were still alive) was found to be 99.5%.[15]

The information on long-term survival and causes of death reported in this chapter represents the merging of all data from the National Database, the collaborative studies, and the Social Security Administration. Although a few

misclassifications of vital status will occur from using the Social Security Administration data, their impact on the results is negligible and far outweighed by the benefits of using these data to increase follow-up and identify deceased persons of whom the Model Systems were unaware. The overall data-merging process enhanced the quality of the data by increasing the study population size from 14,791 to 17,349 persons and increasing the length of follow-up for many of these individuals. However, the last collaborative study included follow-up only to the end of 1985, and the last Social Security Administration file search was conducted in 1989. Therefore, follow-up remains incomplete for many persons. For purposes of this report, all data collection ceased as of June 30, 1992.

LONG-TERM SURVIVAL

Cumulative survival was analyzed using standard Cutler-Ederer life table techniques.[37] In addition, the number of person-years of follow-up was calculated, with each person contributing 1 person-year for each year followed from injury until death, loss, or study termination.[38] Expected numbers of deaths and cumulative survival rates in the absence of SCI were calculated by applying U.S. population annual mortality rates to the actual follow-up period for each individual. These rates were published by the federal government for the year 1982 (the midyear of the study period) and were specific for age, sex, and race.[39]

The overall 18-year cumulative survival for persons injured since 1973 who survived at least 24 hours postinjury and were treated at a Model System within 1 year of injury was 74.6% (Figure 14–1). This compared with an expected cumulative survival in the absence of SCI of 92.4%.

Actual and expected mortality during each year after injury appears in Figure 14–2. The mortality rate for persons with SCI was 3.75% during the first postinjury year and 1.61% during the second postinjury year. Over the next 10 years, the mortality rate was approximately 1.2% per year (range 0.9% to 1.5%). After the 12th postinjury year, estimates of the annual mortality rate became increasingly unstable as sample sizes diminished. It does appear, however, that the annual mortality rate was beginning to increase as the population of persons with SCI aged. Annual expected mortality ranged from 0.4% to 0.5% per year.

Since the mean time from injury to admission to the Model System was 31 days, a small bias was introduced into the first-year mortality rate shown in Figure 14–2. This is because the number of persons who died between 24 hours after injury and time of System admission could not be determined. In a previous Model System study of postinjury survival from 1973 to 1985, first-year mortality increased to 6.3% when only persons admitted within 24 hours of injury were considered.[15] This bias would also have a small effect on the 18-year cumulative survival shown in Figure 14–1.

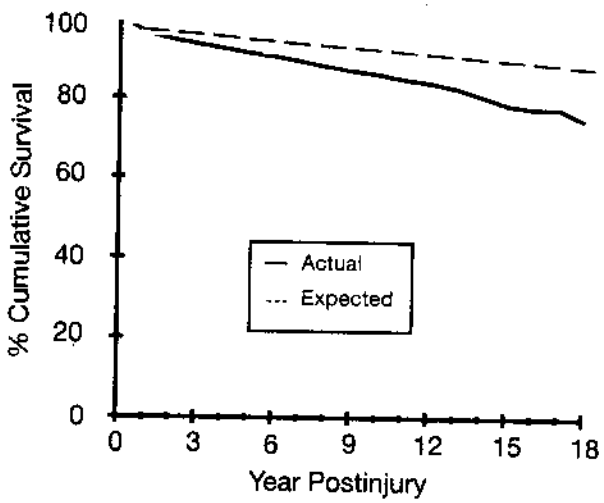

Figure 14–1 Cumulative Actual and Expected Survival for Persons with Spinal Cord Injuries Who Survive at Least 24 Hours Postinjury

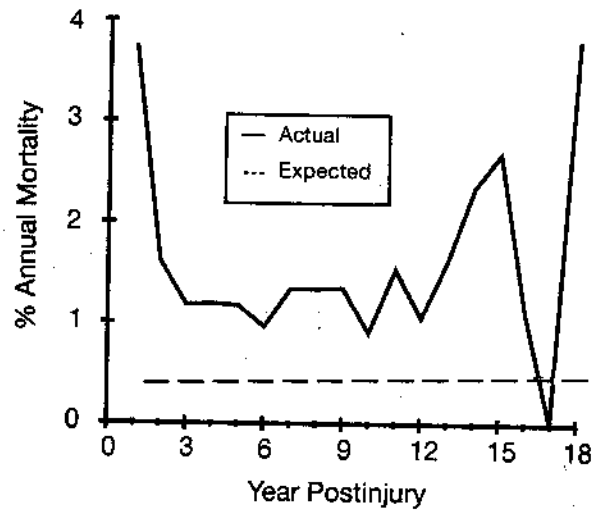

Figure 14–2 Actual and Expected Mortality during Each Year after Spinal Cord Injury for Persons Who Survive at Least 24 Hours Postinjury

As in previous studies, survival rates were strongly associated with neurologic level of injury, Frankel grade,[40] and age at injury.[5,12–16,20–24] In previous studies in which stratified (grouped) analyses were performed, the injury severity strata most often used were incomplete paraplegia, complete paraplegia, incomplete tetraplegia, and complete tetraplegia. The severity of neurologically incomplete lesions varies widely, however, with survival rates for persons who have only sensory sparing (Frankel grade B) or nonfunctional motor capability (Frankel grade C) below the injury level being closer to those of persons with neurologically complete lesions (Frankel grade A) than to persons with functional motor capability below the injury level (Frankel grade D). Moreover, among persons with tetraplegia, substantial differences in survival rates occur at each neurologic level.[15] Therefore, a more effective way to group persons with SCI that maximizes differences in survival rates is to create the following four groups: (1) injury level between C1 and C4 with Frankel grade A, B, or C; (2) injury level between C5 and C8 with Frankel grade A, B, or C; (3) thoracic, lumbar, or sacral injury with Frankel grade A, B, or C; and (4) Frankel grade D regardless of injury level.

Ten-year cumulative survival for each of these groups by age at injury appears in Figure 14–3. As can be seen, survival rates vary dramatically across strata. Persons in the oldest age group have relatively poor prognoses regardless of neurologic category. In fact, more than half of all persons in group 1 over 60 years of age at injury die within the first postinjury year. Older persons in group 1 who survive this initial high-risk period, however, have substantially improved survival rates thereafter. Conversely, cumulative 10-year survival rates are almost normal for persons in group 4 who are less than 46 years of age and persons in group 3 who are less than 31 years of age.

A simpler approach to quantifying long-term survival prospects for persons with SCI is to calculate a measure of average length of future survival. One such measure, commonly referred to as median survival, is the point in time at which 50% of the population has died. Because the Model System program did not begin until 1973, median survival has not yet been reached for several strata. Median survival time was 14.4 years for persons in group 1 (high tetraplegia, C1 to C4) between 31 and 45 years of age at injury, and 18.0 years for persons of comparable age in group 2 (low tetraplegia, C5 to C8). Median survival times for persons in these two neurologic groups who were between 46 and 60 years of age at injury were 6.7 and 13.3 years, respectively. Among persons over 60 years of age at injury, median survival times for the four neurologic groups were 0.9 years for group 1, 3.0 years for group 2, 7.7 years for group 3 (paraplegia), and 10.3 years for group 4 (Frankel grade D).

A second and perhaps more popular measure is life expectancy, which is defined as the arithmetic average (mean) remaining years of life for an individ-

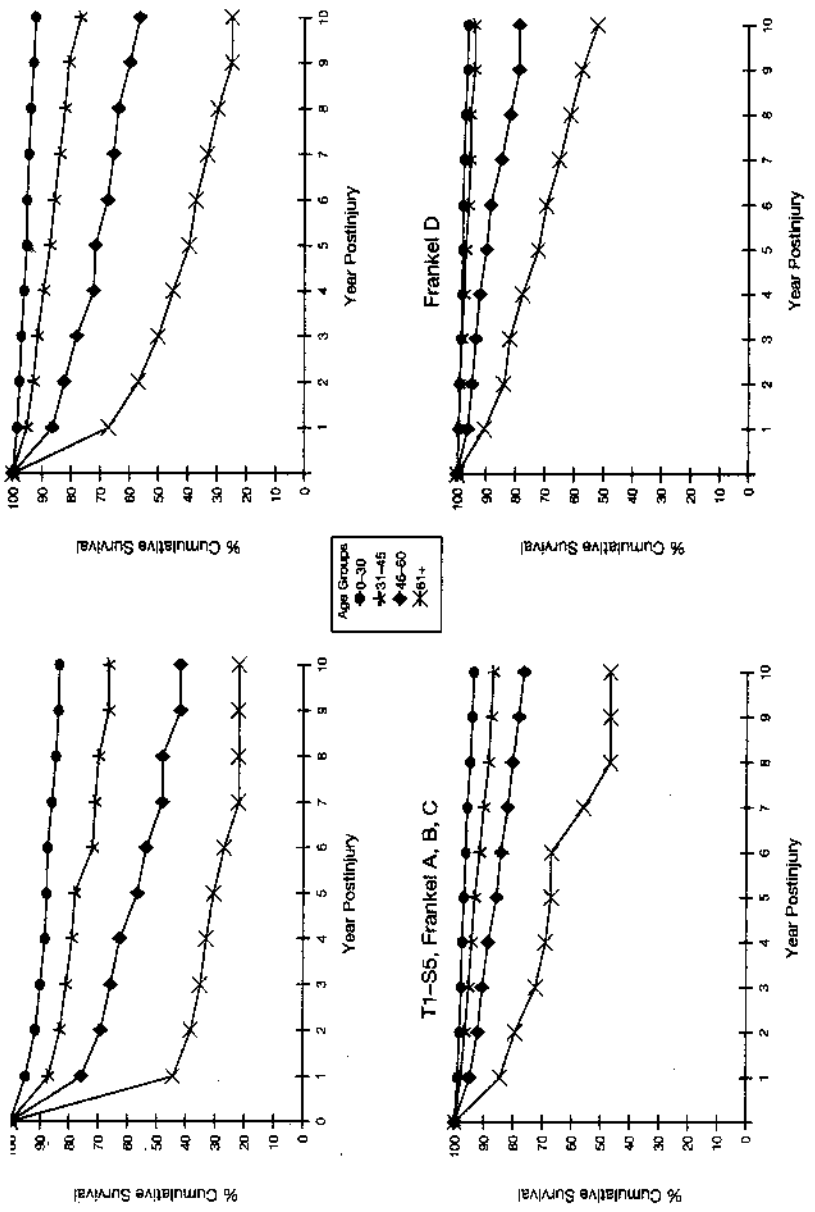

Figure 14–3 Ten-Year Cumulative Survival for Neurologic Groups by Age at Injury

ual. The process by which life expectancies for persons with SCI can be calculated has been discussed in detail elsewhere.[41] After determining the actual and expected number of deaths as discussed previously, the ratio of actual to expected deaths is calculated for each stratum. This is known as either the standardized mortality ratio (SMR) or the relative mortality ratio (RMR). An SMR of 1.0 implies that there is no increase in the mortality rate, whereas an SMR of 2.0 implies that the mortality rate for persons with SCIs in that stratum is twice the rate for the general population of comparable age, sex, and race. These ratios are sometimes multiplied by 100 and expressed as percentages so that an SMR of 1.5 would be expressed as 150% of normal. The annual probabilities of dying in the general population that appear in the standard life table published by the federal government are then multiplied by the appropriate SMR. These revised mortality probabilities are subtracted from 1.0 to get the corresponding survival probabilities that are then multiplied in a cumulative manner to arrive at the cumulative survival probability for each year after injury. Life expectancy (in years) is calculated as the sum of these cumulative survival probabilities.

Standardized mortality ratios for the Model System study population stratified by age at injury and neurologic group appear in Table 14–1. Because of the relatively high mortality experienced during the first postinjury year, a second set of SMRs was calculated with actual and expected deaths during the first postinjury year excluded. Although the exact pattern is somewhat inconsistent, in general, the SMR declines with advancing age and reduced injury severity. The SMR is consistently lower when the first postinjury year is excluded. It has also been demonstrated that the SMR decreases with advancing time after injury.[13]

Estimated life expectancies by age at injury and neurologic group for persons who survive at least 24 hours after injury appear in Table 14–2. These life expectancies are based on the SMR values with the first postinjury year included that appear in Table 14–1. Normal life expectancies for the general population taken from the standard life tables published by the federal government for the year 1988 (the most recent available) are included for comparison purposes.[42] These estimates of life expectancies are substantially higher than those that were published during the mid-1980s.[5,43,44] An individual in neurologic group 1 injured at 25 years of age now has a life expectancy that is 43.4% of normal, while the same individual in neurologic group 4 now has a life expectancy that is 83.9% of normal.

Estimates of life expectancy by current age and neurologic group for persons who survive the first postinjury year appear in Table 14–3. These estimates are based on the SMR values with the first postinjury year excluded that appear in Table 14–1. Figures for normal life expectancy are the same as those that appear in Table 14–2. Not surprisingly, given the difference in SMR values, the estimates appearing in Table 14–3 are uniformly higher than those shown in

Table 14–1 Standardized Mortality Ratios for Persons with Spinal Cord Injuries with First Postinjury Year Included and Excluded by Age at Injury and Neurologic Category

		Standardized Mortality Ratio			
First Postinjury Year	*Age at Injury*	*C1–C4 (Frankel Grade A, B, C)*	*C5–C8 (Frankel Grade A, B, C)*	*T1–S5 (Frankel Grade A, B, C)*	*Frankel Grade D*
Included	0–30	14.47	5.83	4.22	2.93
	31–45	16.98	7.85	4.27	2.04
	46–60	9.53	5.52	2.44	1.99
	61+	9.22	5.37	3.01	1.95
Excluded	0–30	10.94	5.07	3.86	2.58
	31–45	9.78	6.30	3.74	2.03
	46–60	5.24	3.83	1.96	1.66
	61+	3.07	3.07	2.21	1.68

Table 14–2. Nonetheless, these life expectancy estimates are still well below normal, particularly for more severely injured persons.

There is a common misconception, often expressed by many rehabilitation professionals, that as a result of recent medical advances, life expectancy for persons who survive the first postinjury year is either normal or reduced by at most 10%. While much progress has been made, there is clearly no justification for such statements. An individual in neurologic group 1 who has survived at least 1 year after injury and is now 25 years of age has a life expectancy that is 57.9% of normal, while the same individual in neurologic groups 2, 3, and 4 now has a life expectancy that is 67.2%, 79.1%, and 86.6% of normal, respectively.

While projections of life expectancy contained in Tables 14–2 and 14–3 are of great use in tracking progress in the overall medical management of persons with SCI, great caution should be exercised when applying these figures to individual cases for several reasons. First, considerable variability in injury severity exists within each neurologic group. This is particularly true for neurologic groups 1 and 4. For example, the tabulated life expectancies for persons in neurologic group 1 would be overestimates for individuals who were ventilator dependent and underestimates for persons who were not ventilator dependent. Second, the effects of gender, race, and other known determinants of general population survival are not considered. Moreover, the effects of numerous psychosocial factors and the anticipated lifetime quality of care are also not considered, although they are difficult to quantify. Therefore, more precise projections should be made for specific persons only by matching such characteristics of the individual as the exact neurologic level of injury and Frankel

Table 14–2 Life Expectancy for Persons with Spinal Cord Injuries Who Survive at Least 24 Hours Postinjury by Age at Injury and Neurologic Category

	Life Expectancy (Years)				
Age at Injury	*Normal**	*C1–C4 (Frankel Grade A, B, C)*	*C5–C8 (Frankel Grade A, B, C)*	*T1–S5 (Frankel Grade A, B, C)*	*Frankel Grade D*
5	70.8	37.3	47.7	55.7	61.4
10	65.9	32.9	43.1	51.0	56.6
15	61.0	28.5	38.4	46.3	51.8
20	56.3	25.3	34.3	42.1	47.5
25	51.6	22.4	30.5	38.1	43.3
30	46.9	19.3	26.5	34.0	39.0
35	42.2	16.5	22.9	30.0	34.6
40	37.6	14.2	19.5	26.2	30.3
45	33.0	12.2	16.4	22.6	26.0
50	28.6	9.7	13.1	18.7	21.9
55	24.4	7.3	10.2	15.0	18.1
60	20.5	5.0	7.8	11.6	14.8
65	16.9	3.5	5.8	8.9	11.8
70	13.6	2.2	4.0	6.7	9.0
75	10.7	1.3	2.7	4.8	6.7
80	8.1	0.3	1.6	3.2	4.6

*Normal values are from 1988 U.S. Life Tables for the general population.

grade, age, gender, race, ventilator status, length of postinjury survival to date, presence of pre-existing or unrelated concurrent medical conditions, motivation in self-care, and availability of good medical care to the largest possible sample population.

Finally, because of their uncertain nature, these projections cannot take into consideration possible future advances in medical treatment and prevention practices, not only for potentially fatal secondary medical complications related to SCI, but also for unrelated medical conditions such as cancer, heart disease, and stroke that nonetheless affect life expectancy for persons with SCIs. In fact, by using Cox proportional hazards regression analysis to control for confounding due to trends over time in age, gender, race, and neurologic category, a striking trend toward improving survival rates is clearly evident.[45] As seen in Table 14–4, the mortality rate for persons injured between 1976 and 1979 was 0.92 times the mortality rate for persons injured in the referent time period (1973-1975). Stated simply, this means that given comparable age, gender, race, and neurologic category, the mortality rate for 1976–1979 was 8% lower than the mortality rate for 1973–1975. Similarly, the mortality rate was reduced by 25%

Table 14–3 Life Expectancy for Persons with Spinal Cord Injuries Who Survive at Least 1 Year Postinjury by Current Age and Neurologic Category

	Life Expectancy (Years)				
Current Age	*Normal**	*C1–C4 (Frankel Grade A, B, C)*	*C5–C8 (Frankel Grade A, B, C)*	*T1–S5 (Frankel Grade A, B, C)*	*Frankel Grade D*
5	70.8	45.0	52.0	59.5	63.0
10	65.9	40.5	47.3	53.7	58.2
15	61.0	36.1	42.6	49.0	53.4
20	56.3	32.8	38.6	44.8	49.0
25	51.6	29.9	34.7	40.8	44.7
30	46.9	26.8	30.7	36.7	40.5
35	42.2	23.7	27.0	32.7	36.1
40	37.6	20.9	23.6	28.8	31.7
45	33.0	18.4	20.4	25.1	27.5
50	28.6	15.5	17.0	21.2	23.4
55	24.4	12.8	13.8	17.3	19.5
60	20.5	11.0	11.2	13.8	15.9
65	16.9	8.8	8.8	10.9	13.2
70	13.6	6.6	6.6	8.3	10.4
75	10.7	4.7	4.7	6.1	8.0
80	8.1	3.1	3.1	4.2	6.1

*Normal values are from 1988 U.S. Life Tables for the general population.

for persons injured between 1980 and 1982, by 28% for persons injured between 1983 and 1985, by 37% for persons injured between 1986 and 1988, and by 42% for persons injured between 1989 and 1992 relative to persons injured between 1973 and 1975. This improvement represents one of the major accomplishments of the Model System program.

Table 14–4 also confirms the necessity for taking race and gender into account when projecting life expectancy for individuals with SCIs. While these factors are somewhat less important than neurologic category, the mortality rate for males is 27% higher than that for females, and the mortality rate for nonwhites is 19% higher than that for whites given comparable neurologic category, age, and injury year.

CAUSES OF DEATH

Why is life expectancy below normal, even for persons who survive the initial high-risk period immediately after injury? To answer this question, one must

Table 14–4 Results of Proportional Hazards Regression Analysis of Survival Following Spinal Cord Injury

Predictor	*Relative Risk*
Male	1.27
Female	1.00
Nonwhite	1.19
White	1.00
Each Year of Age	1.06
Neurologic Category	
C1–C4, Frankel Grade A, B, C	5.42
C5–C8, Frankel Grade A, B, C	2.72
T1–S5, Frankel Grade A, B, C	1.53
Frankel Grade D	1.00
Year of Injury	
1973–75	1.00
1976–79	0.92
1980–82	0.75
1983–85	0.72
1986–88	0.63
1989–92	0.58

consider cause-specific mortality rates for persons with SCI compared with those of the general population. The methodology for doing this is the same as was used to calculate the SMR values shown in Table 14–1 except that cause-specific mortality rates for the general population are used rather than overall mortality rates to determine the expected number of deaths from each cause. The general population mortality rates for each cause are also age-, sex-, and race-specific so that differences in these characteristics between the general and the SCI population can be controlled.[39] The expected number of deaths from each cause is then compared with the actual number of deaths from that cause to arrive at a separate SMR for each cause. A more detailed understanding of why life expectancy remains below normal can then be obtained by stratifying the cause-of-death analyses by age, neurologic group, and time postinjury.[32,33]

Before proceeding further, it is important to understand that when someone with SCI dies, multiple causes (sometimes even unrelated causes) may play a role in that death. The same is true for persons in the general population. The cause-specific mortality rates for the general population published by the National Center for Health Statistics, however, are based solely on the underlying cause of death. Contributing causes and incidental findings are not considered. For these purposes, the underlying cause of death is defined as the cause that initiated the sequence of events that directly led to the person's death. It is often different

from the immediate cause of death. For example, if the death certificate lists cardiorespiratory arrest due to or as a consequence of pneumonia, then cardiorespiratory arrest would be the immediate cause of death and pneumonia would be the underlying cause of death. Although comparison of causes of death between the SCI and general population by calculating the SMR is therefore restricted to the underlying cause, frequencies and descriptive information about secondary or contributing causes among the SCI population are included to provide a more complete picture of the impact of particular causes on life expectancy.

The results of these analyses appear in Tables 14–5 through 14–9. Because most specific causes of death are relatively rare, particularly among younger-aged persons who comprise the largest segment of the SCI population, sample sizes preclude use of multivariate analyses, even though our study population includes over 17,000 persons. Therefore, age, neurologic group, and time postinjury were analyzed separately rather than jointly (Tables 14–7 through 14–9).

Pneumonia and Other Respiratory Diseases

The leading cause of death for persons with SCIs is pneumonia. Overall, 16.3% of all deaths of known cause were due to pneumonia (Table 14–5). Pneumonia was also listed as a contributing cause of an additional 21 deaths (1.5%). Pneumonia is the leading underlying cause of death in all age groups, ranging from 20.3% in the oldest age group to 12.8% in the youngest age group. It is the leading underlying cause of death in persons with high-level (C1 to C4) tetraplegia (24.7%) and persons with low-level (C5 to C8) tetraplegia (19.6%). Pneumonia is also the leading underlying cause of death during all postinjury time periods, ranging from 18.9% during the first postinjury year to 12.7% after the fifth postinjury year.

The actual number of deaths due to pneumonia was 35.6 times the expected number of deaths given the age, gender, race, and length of follow-up of these persons. The pneumonia SMR was particularly high for younger persons (SMR = 65.7) and persons with high-level tetraplegia (SMR = 151.7), and was highest during the first postinjury year (SMR = 83.8). Nonetheless, there were substantially more deaths due to pneumonia than expected for all groups and time periods.

In addition to pneumonia, there were 109 deaths due to other diseases of the respiratory system (58 underlying and 51 secondary). Combining these with the deaths due to pneumonia, respiratory system complications are the underlying cause of death in 20.4% of cases and, accounting for duplication, a secondary cause of death in an additional 3.5% of cases.

Table 14–5 Underlying and Secondary Causes of Death for Persons with Spinal Cord Injuries Who Survive at Least 24 Hours after Injury

Cause of Death*	*Underlying Cause of Death*†		*Secondary Cause of Death*†		*Total*	
	No.	*%*	*No.*	*%*	*No.*	*%*
Septicemia (038)	122	8.7	47	3.3	169	12.0
Cancer (140–239)	71	5.1	8	0.6	79	5.6
Diseases of the Nervous System (320–359)	30	2.1	28	2.0	58	4.1
Ischemic Heart Disease (410–414)	91	6.5	13	0.9	104	7.4
Diseases of Pulmonary Circulation (415–417)	113	8.1	3	0.2	116	8.3
Nonischemic Heart Disease (420–429)	171	12.2	60	4.3	231	16.5
Cerebrovascular Disease (430–438)	41	2.9	12	0.9	53	3.8
Diseases of Arteries (440–448)	17	1.2	16	1.1	33	2.4
Pneumonia and Influenza (480–487)	228	16.3	21	1.5	249	17.7
Other Respiratory Diseases (460–478, 490–519)	58	4.1	51	3.6	109	7.8
Diseases of the Digestive System (520–579)	67	4.8	28	2.0	95	6.8
Diseases of the Urinary System (580–599)	49	3.5	73	5.2	122	8.7
Symptoms and Ill-Defined Conditions (780–799)	102	7.3	112	8.0	214	15.3
Unintentional Injuries (E800–E949)	72	5.1	—	—	72	5.1
Suicide (E950–E959)	80	5.7	—	—	80	5.7
Homicide and Legal Intervention (E960–E978)	15	1.1	—	—	15	1.1
All Other External Causes (E980–E999)	32	2.3	—	—	32	2.3
Residual (All Others)	44	3.1	70	5.0	114	8.1
Total Deaths of Known Cause	1403	100.0				
Unknown	198	—				
Total Deaths	1601					

*ICD-9-CM codes are in parentheses.
†All percentages are based on 1403 deaths of known cause.

Of the 109 deaths due to other diseases of the respiratory system, there were 12 cases of pulmonary congestion ((11.0%); 10 cases of pulmonary collapse (9.2%); 9 cases of acute pulmonary edema (8.3%); 8 cases each of lung abscess and pneumothorax (7.3%); 6 cases each of pleurisy and emphysema (5.5%); 5 cases of bronchitis (4.6%); 4 cases each of asthma and pulmonary insufficiency (3.7%); 2 cases each of pulmonary fibrosis, empyema, and mediastinitis

Table 14–6 Standardized Mortality Ratios for Underlying Cause of Death among Persons with Spinal Cord Injuries Who Survive at Least 24 Hours Postinjury

Cause of Death	*Actual Deaths*	*Expected Deaths*	*SMR*
Septicemia	122	1.9	64.2
Cancer	71	82.0	0.9
Diseases of the Nervous System	30	5.1	5.9
Ischemic Heart Disease	91	78.4	1.2
Diseases of Pulmonary Circulation	113	2.4	47.1
Nonischemic Heart Disease	171	26.7	6.4
Cerebrovascular Disease	41	18.6	2.2
Diseases of Arteries	17	5.0	3.4
Pneumonia and Influenza	228	6.4	35.6
Other Respiratory Diseases	58	12.8	4.5
Diseases of the Digestive System	67	17.8	3.8
Diseases of the Urinary System	49	4.5	10.9
Symptoms and Ill-Defined Conditions	102	7.4	13.8
Unintentional Injuries	72	51.8	1.4
Suicide	80	16.6	4.8
Homicide and Legal Intervention	15	21.8	0.7
All Other External Causes	32	2.3	13.9
Residual	44	23.2	1.9
Unknown	198		

(1.8%); 1 case each of asphyxiation, tracheostomy complications, chronic airway obstruction, upper respiratory infection, and sinusitis (0.9%); and 26 unspecified cases of lung or respiratory system diseases (23.9%).

Pulmonary Embolus

There were 113 deaths for which the underlying cause was coded as a disease of pulmonary circulation (8.1% of all deaths of known cause). All of these deaths were the result of a pulmonary embolus that usually occurs secondary to deep venous thrombosis. Pulmonary embolus was also listed as a secondary cause of death in 3 cases (0.2%). Therefore, respiratory diseases plus pulmonary emboli account for 28.4% of all underlying causes of death in this population, and when secondary causes of death are included, respiratory disease plus pulmonary emboli can be said to contribute to 31.9% of all deaths. Pulmonary emboli were among the leading underlying causes of death for persons in the younger and middle age groups (9.4% and 10.1% of all deaths of known cause, respectively). Pulmonary emboli were the third leading underlying cause of

Table 14–7 Underlying Cause of Death for Persons with Spinal Cord Injuries Who Survive at Least 24 Hours after Injury, by Age

Cause of Death	Age ≤30 Years			Age 31–60 Years			Age ≥61 Years		
	Actual Deaths	Expected Deaths	SMR	Actual Deaths	Expected Deaths	SMR	Actual Deaths	Expected Deaths	SMR
Septicemia	28	0.2	140.0	63	0.8	78.8	31	0.9	34.4
Cancer	6	4.8	1.3	32	38.6	0.8	33	38.6	0.9
Diseases of the Nervous System	12	1.5	8.0	10	2.2	4.5	8	1.5	5.3
Ischemic Heart Disease	7	1.2	5.8	42	32.5	1.3	42	44.7	0.9
Diseases of Pulmonary Circulation	34	0.3	113.3	63	1.1	57.3	16	1.0	16.0
Nonischemic Heart Disease	33	1.7	19.4	60	11.6	5.2	78	13.4	5.8
Cerebrovascular Disease	11	0.8	13.8	16	6.5	2.5	14	11.3	1.2
Diseases of Arteries	2	0.1	20.0	4	1.3	3.1	11	3.5	3.1
Pneumonia and Influenza	46	0.7	65.7	97	2.4	40.4	85	3.4	25.0
Other Respiratory Diseases	11	0.8	13.8	28	4.3	6.5	19	7.7	2.5
Diseases of the Digestive System	18	1.8	10.0	36	10.8	3.3	13	5.2	2.5
Diseases of the Urinary System	12	0.3	40.0	23	1.7	13.5	14	2.5	5.6
Symptoms and Ill-Defined Conditions	24	2.0	12.0	44	3.5	12.6	34	1.9	17.9
Unintentional Injuries	35	31.5	1.1	32	17.2	1.9	5	3.1	1.6
Suicide	40	9.2	4.3	36	6.4	5.6	4	0.9	4.4
Homicide and Legal Intervention	11	12.5	0.9	4	8.9	0.4	0	0.5	0.0
All Other External Causes	16	1.2	13.3	13	1.0	13.0	3	0.1	30.0
Residual	14	3.9	3.6	21	10.3	2.0	9	8.9	1.0
Unknown	49			87			62		

Table 14–8 Underlying Cause of Death for Persons with Spinal Cord Injuries Who Survive at Least 24 Hours after Injury, by Neurologic Category

	C1–C4, Frankel Grade ABC			*C5–C8, Frankel Grade ABC*		
Cause of Death	*Actual Deaths*	*Expected Deaths*	*SMR*	*Actual Deaths*	*Expected Deaths*	*SMR*
Septicemia	27	0.2	135.0	39	0.4	97.5
Cancer	4	7.0	0.6	14	17.1	0.8
Diseases of the Nervous System	15	0.5	30.0	9	1.2	7.5
Ischemic Heart Disease	17	6.7	2.5	22	16.1	1.4
Diseases of Pulmonary Circulation	21	0.2	105.0	32	0.5	64.0
Nonischemic Heart Disease	56	2.5	22.4	54	5.7	9.5
Cerebrovascular Disease	14	1.8	7.8	11	3.9	2.8
Diseases of Arteries	2	0.5	4.0	4	1.1	3.6
Pneumonia and Influenza	91	0.6	151.7	88	1.5	58.7
Other Respiratory Disease	18	1.1	16.4	26	2.7	9.6
Diseases of Digestive System	21	1.5	14.0	17	4.0	4.3
Diseases of Urinary System	10	0.4	25.0	19	1.0	19.0
Symptoms and Ill-Defined Conditions	44	0.7	62.9	37	1.8	20.6
Unintentional Injuries	11	5.5	2.0	26	14.6	1.8
Suicide	3	1.7	1.8	22	4.6	4.8
Homicide and Legal Intervention	0	2.3	0.0	4	5.8	0.7
All Other External Causes	3	0.2	15.0	9	0.6	15.0
Residual	11	2.2	5.0	17	5.1	3.3
Unknown	46			53		
	T1–S5, Frankel Grade ABC			*Frankel Grade D*		
Septicemia	46	0.5	92.0	10	0.7	14.3
Cancer	31	25.6	1.2	22	32.2	0.7
Diseases of the Nervous System	3	1.7	1.8	3	1.7	1.8
Ischemic Heart Disease	29	23.4	1.2	23	32.2	0.7
Dieases of Pulmonary Circulation	34	0.7	48.6	26	0.9	28.9
Nonischemic Heart Disease	27	7.9	3.4	34	10.6	3.2
Cerebrovascular Disease	7	5.2	1.3	9	7.7	1.2
Diseases of Arteries	8	1.3	6.2	3	2.1	1.4
Pneumonia and Influenza	23	1.8	12.8	26	2.5	10.4
Other Respiratory Disease	9	3.8	2.4	5	5.2	1.0

continues

Table 14–8 continued

	T1–S5, Frankel Grade ABC			*Frankel Grade D*		
Diseases of Digestive System	16	6.1	2.6	13	6.3	2.1
Diseases of Urinary System	15	1.3	11.5	5	1.8	2.8
Symptoms and Ill-Defined Conditions	9	2.5	3.6	12	2.4	5.0
Unintentional Injuries	18	18.1	1.0	17	13.6	1.3
Suicide	40	5.9	6.8	15	4.4	3.4
Homicide and Legal Intervention	6	8.5	0.7	5	5.3	0.9
All Other External Causes	15	0.8	18.8	5	0.6	8.3
Residual	12	7.7	1.6	4	8.4	0.5
Unknown	57			42		

death for persons with paraplegia (9.8%), tied for the second leading underlying cause of death for persons with Frankel grade D lesions (11.0%), and the third leading underlying cause of death during the first postinjury year (14.6%). However, the frequency of deaths due to pulmonary emboli decreased substantially with advancing time after injury, accounting for only 2.5% of deaths after the fifth postinjury year.

Overall, pulmonary embolus had the second highest SMR among all causes of death. The actual number of deaths due to pulmonary emboli was 47.1 times the expected number of deaths given age, gender, race, and length of follow-up of these persons. The pulmonary embolus SMR was particularly high for both younger persons (SMR = 113.3) and persons in the middle age group (SMR = 57.3). The pulmonary embolus SMR decreased substantially with decreasing injury severity, ranging from 105.0 for persons with high-level tetraplegia to 28.9 for persons in the Frankel grade D group. Nonetheless, pulmonary embolus had the highest SMR among persons in the Frankel grade D group, the second highest SMR among persons with paraplegia or low-level tetraplegia, and the third highest SMR among persons with high-level tetraplegia. Pulmonary embolus had the highest SMR during the first postinjury year (SMR = 210.0) and the third highest SMR during postinjury years 2 through 5 (SMR = 19.1).

Diseases of the Urinary System

Diseases of the urinary system now account for only a small percentage of underlying causes of death in this population. Overall, there were 49 deaths for which the underlying cause was a disease of the urinary tract (3.5% of all deaths

Table 14–9 Underlying Cause of Death for Persons with Spinal Cord Injuries Who Survive at Least 24 Hours Postinjury, by Length of Postinjury Survival

	Survival <1 Year			*Survival 1–5 Years*			*Survival >5 Years*		
Cause of Death	*Actual Deaths*	*Expected Deaths*	*SMR*	*Actual Deaths*	*Expected Deaths*	*SMR*	*Actual Deaths*	*Expected Deaths*	*SMR*
Septicemia	38	0.4	95.0	56	0.9	62.2	28	0.6	46.7
Cancer	12	14.7	0.8	33	37.7	0.9	26	29.6	0.9
Diseases of the Nervous System	22	1.0	22.0	4	2.4	1.7	4	1.7	2.4
Ischemic Heart Disease	30	14.5	2.1	42	35.8	1.2	19	28.1	0.7
Diseases of Pulmonary Circulation	84	0.4	210.0	21	1.1	19.1	8	0.9	8.9
Nonischemic Heart Disease	89	5.8	15.3	48	10.1	4.8	34	10.8	3.1
Cerebrovascular Disease	17	3.6	4.7	16	8.5	1.9	8	6.5	1.2
Diseases of Arteries	6	1.0	6.0	7	2.3	3.0	4	1.7	2.3
Pneumonia and Influenza	109	1.3	83.8	79	3.0	26.3	40	2.1	19.0
Other Respiratory Diseases	34	2.4	14.2	16	5.9	2.7	8	4.5	1.8
Diseases of the Digestive System	24	3.1	7.7	25	8.2	3.0	18	6.5	2.8
Diseases of the Urinary System	14	0.9	15.6	20	2.1	9.5	15	1.5	10.0
Symptoms and Ill-Defined Conditions	56	1.3	43.1	32	3.5	9.1	14	2.6	5.4
Unintentional Injuries	11	9.5	1.2	32	25.8	1.2	29	16.5	1.8
Suicide	13	2.6	5.0	49	8.0	6.1	18	6.0	3.0
Homicide and Legal Intervention	1	4.1	0.2	7	14.9	0.5	7	2.8	2.5
All Other External Causes	3	0.4	7.5	12	1.1	10.9	17	0.8	21.3
Residual	13	3.8	3.4	14	8.7	1.6	17	10.7	1.6
Unknown	36			89			73		

of known cause). However, diseases of the urinary system were listed as a secondary contributing cause of death for an additional 73 persons (5.2%), making this the most frequent secondary cause of death among persons with SCIs.

Of 122 deaths for which diseases of the urinary system were either the underlying or secondary cause, only 13 were due to renal failure (10.7%). There were 40 urinary tract infections (32.8%), most of which were listed as secondary causes of death. There were 19 cases of glomerulonephritis (15.6%); two cases of kidney stones (1.6%); one case each of kidney cyst, cystitis, and unspecified bladder disease (0.8%); and 45 cases of unspecified kidney disease (36.9%).

The actual number of deaths due to diseases of the urinary system was 10.9 times the expected number of deaths given age, gender, race, and length of follow-up of these persons. The SMR for diseases of the urinary system decreased with advancing age and with decreasing injury severity. However, no trend in the SMR for diseases of the urinary system was observed by time postinjury.

Septicemia

Septicemia is the third leading underlying cause of death for persons with SCIs. Overall, there were 122 deaths for which the underlying cause was septicemia (8.7% of all deaths of known cause). Septicemia is usually secondary to an infection occurring in any of several organ systems of the body. Unfortunately, the source of septicemia is often not documented on death certificates. Among the 122 deaths where septicemia was listed as the underlying cause, 27 cases were actually secondary to pressure sores (22.1%). These deaths were included in the septicemia category rather than in a newly created category for diseases of the skin. The source of 55 cases of septicemia was not documented (45.1%), while the remaining 40 cases were included in this category because they had multiple possible sources listed as contributing causes of death (32.8%).

In addition, septicemia was listed as a secondary cause of death for 47 cases (3.3%). Of these, 23 were secondary to urinary tract infections (48.9%), 18 were secondary to respiratory infections (38.3%), and 6 were secondary to peritoneal infections (12.8%). This generally agrees with others who reported that urinary tract infections were the source of bacteremia in 47% of cases.[46]

Septicemia is tied for the second leading underlying cause of death in the middle-aged-group (10.1%), the leading underlying cause of death among persons with paraplegia (13.2%), the third leading underlying cause of death

among persons with low-level tetraplegia (8.7%), and the second leading underlying cause of death between 1 and 5 years postinjury (10.9%). Overall, septicemia has the highest SMR of any cause of death in this population (SMR = 64.2). It has the highest SMR across all age groups, the second highest SMR among persons with either high-level tetraplegia or Frankel grade D lesions, the highest SMR among persons with either low-level tetraplegia or paraplegia, the highest SMR after the first postinjury year, and the second highest SMR during the first postinjury year.

Many of these deaths might be preventable with appropriate skin care, proper supplies and equipment, routine long-term follow-up, and improved compliance with therapeutic regimens. Therefore, increased emphasis should be placed on patient education, particularly in the areas of proper skin care and bladder management. Regular home visits by skilled personnel trained to identify and manage problems before they become life-threatening may also prove beneficial for some persons with SCIs. Nonetheless, many infections are probably not preventable in this population. Therefore, prompt and appropriate treatment of infections when they occur in these organ systems is also important in preventing septicemia.

Diseases of the Digestive System

There were 67 deaths for which diseases of the digestive system were listed as the underlying cause (4.8% of all deaths of known cause). In addition, diseases of the digestive system were listed as a secondary contributing cause of death in 28 cases (2.0%). Of the 95 total cases in which diseases of the digestive system were cited as either the underlying or a contributing cause of death, 39 (41.1%) were cases of peritonitis or gastrointestinal hemorrhage usually secondary to perforated and/or hemorrhaging ulcers; 25 (26.3%) were diseases of the liver (usually alcoholic cirrhosis); 16 (16.8%) were intestinal disorders, including obstructions, adhesions, fistulas, and enteritis; 5 (5.3%) were pancreatic diseases; 5 (5.3%) were unspecified vascular insufficiencies; and there was 1 case each of obstructed inguinal hernia, unspecified disorder of gastric motility, unspecified disorder of the esophagus, unspecified disorder of the stomach, and acute appendicitis (1.1%).

Diseases of the digestive system were not among the leading underlying causes of death for any age, neurologic, or time postinjury group. Nonetheless, there were 3.8 times more deaths due to diseases of the digestive system than expected in this population. While this is not an exceptionally high SMR compared with other causes, it does suggest that digestive system complications cannot be ignored as a contributor to reduced life expectancies in this population,

particularly among young persons for whom the SMR was 10.0 and among persons with high-level tetraplegia for whom the SMR reached 14.0.

Unintentional Injuries, Suicide, and Homicide

By definition, all deaths in these categories begin with a traumatic event. Therefore, these events will always constitute the underlying cause rather than a secondary cause of death.

There were 72 deaths due to unintentional injuries that occurred subsequent to the event that caused the SCI (5.1% of all deaths of known cause). This was only slightly more than the expected number of deaths from this cause (SMR = 1.4). Unintentional injuries were not among the leading underlying causes of death for any neurologic group or time postinjury. However, they were the third leading underlying cause of death for persons in the youngest age group (9.7%). This is not surprising, since unintentional injuries are the leading cause of death in the younger-aged general population.[42]

Recently, attention has been focused on the relatively high rate of suicide in this population.[34–36] The data presented in Tables 14–5 through 14–9 confirm this disturbing trend. There were 80 confirmed suicides in this population (5.7% of all deaths of known cause). Suicide was the second leading underlying cause of death among persons in the youngest age group (11.1%), the second leading underlying cause of death for persons with paraplegia (11.5%), and the third leading underlying cause of death between the first and fifth postinjury years (9.6%). Conversely, suicide was rare among persons with high-level tetraplegia.

The overall SMR for suicide was 4.8. The highest suicide SMR was for persons with paraplegia (SMR = 6.8). The suicide SMR was higher during the first 5 years than later postinjury. These trends are similar to those reported previously.[36] Additional analyses and discussion of the issue of suicide in this population appears in Chapter 10, and other reports have also been published.[34–36]

Very few persons in this population were homicide victims (1.1% of all deaths of known cause). Moreover, the number of homicides was slightly below that which was expected given the age, gender, race, and length of postinjury follow-up for this population (SMR = 0.7).

There were 32 deaths due to "all other external causes." These are invariably cases of fatal injuries that were sustained from events of uncertain circumstances. Since there were 72 confirmed unintentional injuries, 80 confirmed suicides, and 15 confirmed homicides, it might be assumed that approximately these same proportions should apply to the 32 cases of uncertain circumstances. If that were true, then these 32 cases would include 14 deaths due to unintentional injuries, 15 suicides, and 3 homicides. This would increase the overall SMR to 1.7 for unintentional injuries, 5.7 for suicide, and 0.8 for homicide.

Cardiovascular, Cerebrovascular, and Arterial Diseases

Nonischemic heart disease is the second leading underlying cause of death in this population, while ischemic heart disease ranks sixth. Combining these two categories, heart disease accounts for 18.7% of all deaths of known cause, ranking second only to pneumonia and other diseases of the respiratory system as the underlying cause of death. In addition, there were 71 deaths (5.1%) for which heart disease was listed as a secondary contributing cause (58 nonischemic, 11 ischemic, and 2 with both). After eliminating duplication among the underlying and secondary causes, heart disease contributes to 22.4% of all deaths.

If both ischemic disease and nonischemic disease are combined, then heart disease is the second leading underlying cause of death among persons with tetraplegia and the leading underlying cause of death among persons with paraplegia and persons with Frankel grade D injuries. Heart disease would also be the second leading underlying cause of death during the first 5 postinjury years, and the leading underlying cause of death thereafter.

Interestingly, there is no significant increased risk of mortality due to ischemic heart disease in this population (SMR = 1.2). However, it is possible that follow-up is not yet long enough for significant increases in mortality due to ischemic heart disease to appear. There is a significant increase in mortality due to nonischemic heart disease (SMR = 6.4) that requires further scrutiny.

Among the 231 deaths for which nonischemic heart disease was either the underlying or secondary cause, 98 (42.4%) were classified as cardiac arrests not otherwise specified (ICD9CM code 427.5). The remaining 133 causes of death in this category included 71 cases of congestive and other heart failure, 40 cases of cardiac dysrhythmia, 19 cases of ill-defined heart disease, two cases of endocardial disorders, and one case of cardiomyopathy.

Closer inspection of the 98 deaths coded as cardiac arrests not otherwise specified revealed that this category was often used in cases where the cause of death appeared uncertain. These are virtually always listed as immediate causes of death with no secondary cause listed. These deaths often occur during the first postinjury year. Many of these individuals are young and have no previous history of heart disease, and only 30% of these cases were autopsied. It is likely that several of these cases represent sudden death secondary to vagal arrest rather than intrinsic heart disease, particularly among persons with high-level tetraplegia.[47] Therefore, the true number of deaths due to nonischemic heart disease is probably considerably overestimated. Nonetheless, even if all suspect deaths were excluded from the nonischemic heart disease category, there would still be almost three times as many deaths remaining as expected.

Unlike ischemic heart disease, there is a small increase in mortality due to cerebrovascular disease (SMR = 2.2). Overall, cerebrovascular disease was the underlying cause of 2.9% of all deaths of known cause. Cerebrovascular disease

also contributed as a secondary cause to 12 additional deaths (0.9%). Cerebrovascular disease was not among the leading underlying causes of death for any study group, and SMR values were consistently small by comparison with other causes.

Diseases of the arteries were also a relatively rare underlying cause of death (1.2% of all deaths of known cause). However, the overall SMR was somewhat elevated (SMR = 3.4). Among older persons, the usual cause of death in this category was arteriosclerosis, while among younger persons aneurysms were the usual cause. Diseases of the arteries were also listed as a secondary contributing cause of death for 16 cases (1.1%). In almost all of these secondary cases, heart disease or cerebrovascular disease was listed as the underlying cause of death.

Although the SMRs for heart disease, cerebrovascular disease, and diseases of the arteries are not particularly high relative to those of other causes, there are nonetheless a substantial number of excess deaths due to these combined causes. Therefore, these data suggest that smoking cessation, changing diet, and increasing exercise to the extent possible would have an even greater impact on life expectancy of persons with SCIs than they would in the general population.

Cancer

Cancer mortality rates do not appear to be increased among persons with SCI. Overall, 5.1% of all deaths of known cause were due to cancer. Cancer was also listed as a contributing cause of an additional eight deaths (0.6%). Of 79 deaths where cancer was either the underlying or a contributing cause, 27 were metastatic lung disease (34.2%). There were six prostate cancers (7.6%); five colorectal cancers (6.3%); four pancreatic malignancies (5.1%); three each of the brain, esophagus, bladder, and connective and soft tissue of the head, face, and neck (3.8%); two each of liver, kidneys, endocrine glands, leukemia, and multiple myeloma (2.5%); and one each of urinary system (unspecified), endometrium, ovary, breast, bone, peritoneum, melanoma, and other malignant neoplasm of the skin (1.3%). The remaining seven cases were disseminated or unspecified malignancies (8.9%). This pattern of cancers seems consistent with what one would expect in the general population of comparable age, sex, and race. Cancer would be expected to increase as a cause of death as the population is followed longer and ages.

Other Causes of Death

There were 30 deaths for which the underlying cause was listed as a disease of the nervous system (2.1%). In addition, diseases of the nervous system were listed as a secondary contributing cause of death in 28 other cases (2.0%). These

figures do not include any persons with ICD9CM code 344 (other paralytic syndromes) because these codes typically are used to represent the SCI itself. Four cases of meningitis, three cases of abscesses, and two cases of epilepsy were documented. The exact nature of the remaining 49 cases was unspecified.

Interestingly, most of these deaths occur among persons with high-level tetraplegia during the first postinjury year. In fact, although the overall SMR is 5.9, the SMR for persons with high-level tetraplegia is 30.0, and the SMR for the first postinjury year is 22.0. Given the unspecified nature of most of these reported deaths, there may be some overestimation of deaths in this category due to potentially inappropriate use of these nonspecific central nervous system codes in cases when either the exact cause of death is unknown or the death occurs very shortly after injury and is attributed to the injury itself. Autopsies were performed on only 30% of cases for which diseases of the nervous system were the underlying cause.

Another indicator of the relatively poor quality of information contained on many death certificates is the exceptionally high rate of reported deaths due to symptoms and ill-defined conditions. Overall, symptoms and ill-defined conditions were listed as the underlying cause of death in 7.3% of cases and as a secondary contributing cause in an additional 8.0% of cases. The SMR for symptoms and ill-defined conditions was 13.8; however, once again, most of these deaths occur during the first postinjury year (SMR = 43.1) and among persons with high-level tetraplegia (SMR = 62.9). Most of these cases are coded in the respiratory arrest (ICD9CM code = 799.1) subcategory of "other ill-defined and unknown causes of morbidity and mortality." Therefore, many of these cases might be more appropriately classified in the "other respiratory disease" category described previously. If so, this would substantially increase the percentage of total deaths due to diseases of the respiratory system.

Finally, there were 44 deaths for which the underlying cause was "none of the above" (3.1% of all deaths of known cause). In addition, 70 other cases had residual secondary causes of death (5.0%). The most frequent residual cause of death was infectious diseases (n = 20), followed by diabetes mellitus (n = 15), nutritional deficiencies (n = 12), unspecified diseases of the circulatory system (n = 12), acquired immune deficiency syndrome (n = 8), hyperosmolality (n = 7), hypertension (n = 6), osteomyelitis (n = 5), coagulation defects (n = 5), and assorted others (n = 24). Because these causes were listed slightly more frequently than expected as the underlying cause of death (SMR = 1.9), it appears that many of these deaths were probably related to SCI.

Cause of Death Data Limitations and Biases

Cause of death information was unavailable for 198 persons (12.4% of deaths). These are often persons who are not actively followed by the Model System but

who instead either return to the care of their local community physician or receive little or no care. Frequently, these deaths are identified only through Social Security Administration records that provide dates and locations of death but not causes.

Acquisition of death certificates is often unrevealing. Unfortunately, attributing cause of death on death certificates simply to SCI or the original event that caused the injury without identifying the secondary complications that actually caused death is relatively common, even when the individual has survived several years after the injury. As a result, the percentage of deaths due to unknown causes is relatively high. Moreover, as in the general population, autopsies are not always performed on persons with SCI, even when cause of death is uncertain. In fact, only 38% of the causes of death appearing in Tables 14–5 through 14–9 were confirmed by autopsy.

Because the person-years that these individuals with unknown causes of death survived until the time of their deaths were included in the calculation of expected deaths, the cause-specific SMRs are slightly underestimated. In general, the higher the SMR, the greater the underestimation due to unknown causes is likely to be. Therefore, the greatest impact would probably be on the SMR for septicemia. For example, if the 198 deaths of unknown cause were allocated in accordance with the distribution of known causes of death, then 17 additional deaths would be expected to have resulted from septicemia, thereby bringing the total number of actual deaths to 139 and raising its overall SMR from 64.2 to 73.2. However, adding an anticipated 10 cancer deaths from the 198 deaths of unknown cause would only change the cancer SMR from 0.9 to 1.0.

The SMR will also be underestimated to a somewhat greater degree in the strata that have higher percentages of unknown causes of death. For example, only 5.9% of deaths during the first postinjury year resulted from unknown causes, whereas 18.9% of deaths occurring more than 5 years after injury had unknown causes.

CONCLUSION

In comparing these results with our previous studies of 7- and 12-year survival, it is clear that mortality rates have continued to decline and that corresponding life expectancies have increased.[14,15,43,44] In fact, the sequential results of these studies confirm the improvement in survival rates reflected in Table 14–4. Interestingly, this appears to have occurred largely due to a decline in the overall SMR for septicemia from 140.7 in our first study to 82.2 in our second study and 64.2 currently.[32,33] For persons in the youngest age group (defined originally as less than or equal to age 25), the SMR for septicemia has declined from 500 in our first study to 388.9 in our second study and 140 currently.[32,33] Nonetheless,

the SMR for septicemia remains higher than that of any other cause of death in this population. Overall SMR values for other causes are relatively consistent with the results of our 12-year study, except for a slight increase in unspecified external causes of death.[33]

Because life expectancy is affected more by deaths occurring early after SCI rather than later, the causes of death that appear to have the greatest impact on reduced life expectancy for this population are pneumonia, pulmonary emboli, and septicemia (Table 14–9). With the development of improved methods of prevention and management of these three secondary complications, life expectancies should continue to improve.

The dramatic reduction in mortality due to diseases of the urinary tract clearly demonstrates the value of clinical emphasis and research in the prevention of secondary complications and deaths. The respiratory system has not received the attention that the urinary tract has received over the past years. Therefore, although other types of potentially fatal secondary medical complications that continue to occur among persons with SCI cannot be ignored, these data strongly suggest that increased clinical attention, research, and dissemination activities should be focused on the respiratory system in much the same way they have been focused on the urinary tract.

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