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A prospective assessment of mortality in chronic spinal cord injury

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Abstract

Study design—Prospective mortality study.

Objective— To assess the relationship between comorbid medical conditions and other healthrelated factors to mortality in chronic spinal cord injury (SCI).

Setting— Boston, MA, USA.

Methods— Between 1994 and 2000, 361 males ≥1 year after injury completed a respiratory health questionnaire and underwent pulmonary function testing. Cause-specific mortality was assessed over a median of 55.6 months (range 0.33–74.4 months) through 12/31/2000 using the National Death Index.

Results— At entry, mean (±SD) age was 50.6 ± 15.0 years (range 23–87) and years since injury was 17.5 ± 12.8 years (range 1.0–56.5). Mortality was elevated (observed/expected deaths = 37/25.1; SMR = 1.47; 95% CI = 1.04–2.03) compared to US rates. Risk factors for death were diabetes (RR = 2.62; 95% CI = 1.19–5.77), heart disease (RR = 3.66; 95% CI = 1.77–7.78), reduced pulmonary function, and smoking. The most common underlying and contributing causes of death were diseases of the circulatory system (ICD-9 390–459) in 40%, and of the respiratory system in 24% (ICD-9 460–519).

Conclusions— These results suggest that much of the excess mortality in chronic SCI is related to potentially treatable factors. Recognition and treatment of cardiovascular disease, diabetes, and lung disease, together with smoking cessation may substantially reduce mortality in chronic SCI.

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Keywords

spinal cord injury (SCI); mortality; heart diseases; diabetes; smoking

Introduction

Although there have been improvements in medical care following spinal cord injury (SCI), mortality rates are still elevated compared to the able-bodied.[1–8] The most common causes of death in the first year and thereafter in contemporary studies are pneumonia and other respiratory illnesses.[2,4,5,7,8] Based on retrospective assessments, excess mortality after SCI has been attributed to neurological level and completeness of injury, older age at injury, and injury in earlier calendar years.[1–3,7,8] Risk factors for mortality have never been assessed prospectively in subjects with chronic SCI.

Since 1994 we have been prospectively assessing pulmonary function in a chronic SCI cohort. At study, entry subjects were one or more years following injury, had completed a detailed health questionnaire, and underwent pulmonary function testing and a neurological exam. We used the information collected at study entry to examine prospectively the role of specific respiratory and nonrespiratory health-related factors on mortality.

Methods

Population

Between 10/19/1994 and 12/31/2000, 402 subjects with chronic SCI were recruited to assess longitudinal change in pulmonary function and risk factors for respiratory illness. Subjects had to be at least 20 years of age, free of other neurological diseases, and could not require mechanical ventilation or have a tracheostomy. Recruitment was from a pool of 1636 potential subjects that included 1052 subjects who were previously treated by the SCI Service at Veterans Affairs (VA) Boston Healthcare System, 527 subjects from the National Spinal Cord Injury Association (NSCIA) from Massachusetts, New Hampshire, Vermont, Maine, and Rhode Island, and 57 subjects who had responded to advertising. Recruitment from the VA SCI Service and NSCIA was by letter with a follow-up phone call, and veterans were also approached while at the VA Medical Center for an appointment. There were 340 subjects who could not be contacted due to an outdated address, 73 who could not be tested because they lived too far from the VA Medical Center, 193 who were not interested, three without SCI, five with recent injury, and 224 subjects who were deceased, resulting in 798 potential subjects.

Of the 402 subjects enrolled, 22 were excluded because they were subsequently found to have additional neuromuscular diseases (polio, stroke, or multiple sclerosis). Since there were only 19 women and none was deceased, it was not possible to assess their risk factors for mortality. Therefore, analysis was limited to 361 males (289 veterans and 72 nonveterans). Approval was provided by the Institutional Review Boards at VA Boston, Harvard Medical School and Brigham and Women's Hospital, and informed consent was obtained from each subject.

Assessment of baseline risk factors

Health questionnaire—A respiratory health questionnaire based on the ATS DLD-78 adult respiratory questionnaire[9] was used to obtain a history of respiratory symptoms, cigarette smoking, and comorbid medical conditions. Medication use was also reviewed.

Pulmonary function—Spirometry was based on ATS standards10 modified for use in SCI as previously described.11,12 Briefly, although subjects with SCI are more likely than the able-bodied to have short expiratory efforts and exhibit excessive back extrapolation during testing, we have demonstrated that the FEV_1 and FVC of such efforts are highly reproducible.11,12 Maximum expiratory and inspiratory pressures (MEP, MIP) were measured three times using a pressure transducer and strip chart recorder or computerized data acquisition unit and maximal values reported.13 MEP was measured using a trumpet style mouthpiece that was introduced later in the study, so MEP values were available for fewer subjects.13

Neurological exam, stature, and weight—Motor level and completeness of injury were determined using American Spinal Injury Association (ASIA) guidelines 14 A total of 12 subjects with motor complete cervical injury and 14 subjects with other neurologically complete SCI levels had a zone of partial preservation of more than two neurological levels. In order to consider the effects of a well-defined injury level on mortality in subjects with neurologically complete motor injuries, these subjects were categorized with ASIA C subjects (neurologically incomplete SCI where most key muscles below the level of injury are graded as less than 3/5) instead of with subjects with complete motor SCI. In contrast, in previous studies with detailed information available regarding neurological level, the mortality of subjects with complete motor and ASIA C SCI were reported together.2,5–8 Neurologically incomplete SCI where most key muscles below the level of injury were graded 3/5 or greater were classified as ASIA D. Subjects with incomplete injuries were classified based on the most rostral level that was abnormal. Subjects were weighed and supine length measured.15

Death ascertainment and cause of death

Date of death and cause-specific mortality through December 2000 was ascertained using the National Death Index (NDI). Internal study records identified 37 deaths and no additional deaths were identified by NDI. An exact match based on first and last name and social security number was obtained for all but one death. This subject did not match on the last digit of the social security number, but matched on exact name, date of birth, and state of residence. For 13 subjects, ICD-9 codes for underlying and contributing causes of death were obtained from an NDI record search conducted through 12/31/1998. For the remaining 24 subjects, ICD-10 codes obtained from later searches were converted to ICD-9.

Data analysis

Chronic cough was defined as cough on most days for 3 consecutive months of the year, and chronic phlegm was defined similarly. Any wheeze was wheeze reported most days/nights, wheezing with a cold, or occasionally apart from a cold. Persistent wheeze was wheeze reported on most days or nights, or with a cold and occasionally apart from colds. Smokers were defined as smoking 20 or more packs of cigarettes or using 12 ounces of tobacco or more in a lifetime, or smoking one or more cigarettes per day for at least 1 year. Current smokers reported cigarette use within 1 month of testing. Packyears were calculated by the duration of cigarette smoking multiplied by the usual packs of cigarettes smoked per day. Hypertension, diabetes, and asthma were defined if diagnosed by a doctor, and chronic obstructive pulmonary disease (COPD) was the presence of either doctor-diagnosed emphysema or chronic bronchitis. Heart disease was defined as treatment for ‘heart trouble’ reported in the 10 years prior to study entry.

Predicted levels of pulmonary function provided by Hankinson *et al*16 were available for Caucasians and Blacks. Self-reported height was used for the calculation of body mass index (BMI) and predicted values of pulmonary function in 77 subjects (21%). In these subjects,

length measurement was declined or severe joint contractures precluded accurate assessment. It was not possible to assess stature in one subject injured at birth. In three subjects who did not undergo examination, neurological assessment was based on medical records. In 32 (9%) weight was not measured and stated weight was used.

Medical record review

Medical records were reviewed for subjects who reported diabetes, hypertension, heart disease, or chronic respiratory disease (COPD or asthma). These medical conditions were considered doctor-confirmed if listed as a diagnosis in a discharge summary, problem list, or in a progress note.

Statistical analysis

Proc LIFETEST (SAS 8.0) was used to calculate unadjusted Kaplan–Meier survival curves17 and age-adjusted curves were obtained using a direct standardization approach according to Cupples *et al*.18 Proportional hazards survival models (Proc PHREG) were used to obtain univariate and multivariate estimates of mortality.17 Survival plots of the data were examined to ensure that the proportional hazard assumption was appropriate and time-dependent covariates were constructed appropriately. Variables significant at the 0.1 level in age-adjusted univariate models were included in multivariate models, with backward selection at the 0.05 level. Two-sided 95% confidence limits were obtained. Overall and cause-specific standardized mortality ratios (SMR) were obtained using the Life Table Analysis System (LTAS) provided by the National Institute of Safety and Health.19

Results

Of the 361 males, 93% were Caucasian, 5% were African American, and 2% were of other races, and in 92%, SCI was due to traumatic injury. Of the 28 persons (8%) with nontraumatic causes of SCI, six were due to vascular disease (AV malformation, aneurysm surgery, cord infarction), five were due to infection, three were due to disc disease or spinal stenosis, four were due to tumor, six occurred following an unspecified operation, and four had other causes (birth injury, spina bifida, hereditary paraplegia, and an unknown cause). Subjects were followed for a median of 55.6 months (interquartile range 42.0–67.5 months; range 0.33–74.4 months) and there were 1544 person-years of follow-up. Mean age, years since SCI, age at injury, calendar year of injury, smoking behavior, prevalence of comorbid medical conditions, pulmonary function, and other personal characteristics obtained at entry are provided in Table 1.

Standardized mortality ratios

The overall SMR was 1.47 (95% CI 1.04–2.03). The SMR for subjects with cervical motor complete, cervical C, other motor complete, or other subjects with motor incomplete injuries were not significantly elevated. The SMRs for bladder cancer and osteomyelitis were significantly elevated, whereas SMR values for respiratory or cardiac deaths were not (Table 2).

Causes of death

The most common underlying causes of death (Table 3) were neoplasms (24.3%), followed by circulatory system disorders (21.6%). Respiratory system deaths accounted for only 5.4% of the underlying causes of death. Specific neoplasms included bladder cancer ($n = 3$), and one each for lung, liver, colon, prostate cancer, leukemia, and an unspecified malignant neoplasm. When both underlying and contributing causes of death were considered, diseases of the respiratory and circulatory system contributed to 24.3 and 40.5% of the deaths,

respectively. Specific underlying and contributing respiratory deaths included pneumonia (*n* = 4), chronic airways obstruction (*n* = 3), pleural effusion (*n* = 1), and unspecified respiratory complications (*n* = 1). Specific underlying and contributing circulatory system deaths included heart failure (*n* = 3), atrial fibrillation (*n* = 2), atherosclerosis and ischemic heart disease (*n* = 3), and ventricular tachycardia, abdominal aneurysm rupture, cerebrovascular disease, cardiac arrest, cardiomyopathy, ill-defined heart disease, and pulmonary hypertension in the setting of HIV-related disease (*n* = 1 for each cause). Although 13 patients had a nervous system disease listed as underlying or secondary cause of death, the codes listed reflected SCI (quadriplegia, paraplegia, or vascular myelopathy) rather than other neurologic causes. Of five participants with external causes listed as the underlying cause of death (Table 3), two had codes referring to SCI that occurred as a result of an injury. The three others with death due to external causes appeared to have causes unrelated to SCI. These included poisoning (cocaine and alcohol intoxication), suicide, and a fall causing a traumatic subdural hemorrhage.

Predictors of mortality

Age, years since injury, and SCI level—Based on age at study entry, there was an 8% increased risk of dying per year of age (Table 4). Although years since injury, age at injury, medical causes (compared to nontraumatic causes; Table 4), and earlier calendar year of injury (results not shown) were predictors of mortality in univariate models, these were not significant when ageadjusted. The mortality of subjects with motor incomplete SCI, cervical complete, cervical ASIA C, and others with motor complete SCI was similar. Race (Caucasian *versus* others) was not related to mortality (results not shown).

Cigarette smoking

Adjusted for age, current smokers at study entry had an increase in mortality of 4% per cigarette smoked per day compared to never smokers (Table 4). Subjects who quit smoking within the 7 years prior to study entry also had an elevated mortality risk, whereas subjects who quit more than 7 years prior to study entry did not (Table 4). Lifetime smoking, expressed as pack-years, was not significantly related to mortality (results not shown).

Respiratory symptoms, medical conditions, and pulmonary function

After adjusting for age, any wheeze was a significant predictor and persistent wheeze was a borderline predictor of mortality (Table 4). Heart disease and diabetes were associated with a three- and two-fold increase in risk, respectively. The age-adjusted relative risks of mortality due to hypertension, asthma, COPD, and obstructive lung disease were mildly elevated, but not to a level of statistical significance. After adjusting for age, MIP, MEP, and FEV_1/FVC were not related to mortality, but percent-predicted FEV_1 and percent-predicted FVC were. Age-adjusted models for FEV_1 and FVC indicated that for each percent predicted increase in lung function, mortality decreased by 3% (Table 4).

Multivariate models

In the 348 subjects with pulmonary function data available (Table 5), significant predictors of mortality included age, percent-predicted FEV_1, cigarette smoking (current cigarette consumption and smoking ≤ 7 years before study entry), diabetes, and heart disease. Similar results were obtained using models that included percent-predicted FVC instead of percent-predicted FEV_1. However, the model fit was slightly better in the latter model. Based on a multivariate model, the mortality risk for a one-pack per day current smoker was 2.29, which was similar to subjects who quit smoking within 7 years of study entry. The risk attributable to past cigarette smoking was greatest in models that excluded FEV_1 (Table 5).

Validation of comorbidities

Of 36 subjects who reported doctor-diagnosed diabetes, 34 received health care through VA Boston, and in these cases diabetes was documented by record review. In the 31 subjects with heart disease treated in the 10 years before testing, 30 had records available and in 28 (93%) this diagnosis was verified. Specific heart conditions included 7 (25%) subjects with arrhythmias, mostly atrial fibrillation, and 19 (68%) with coronary artery disease. Out of the 97 subjects who reported hypertension, 80 had a medical record at VA Boston, and in 64 (80%), a history of hypertension was verified. For 51 subjects with obstructive lung disease defined based on responses to the questionnaire, 40 had records available, but the diagnosis was noted in only 20 (50%).

Medication use was available for 350 (97.0%) subjects. Medications categorized as treatment for heart disease included beta-blockers, calcium channel blockers, digoxin, angiotensin-converting enzyme inhibitors, and diuretics. Treatment for hypertension also included alpha-blockers but excluded digoxin. Of the 31 subjects who reported heart disease treated in the past 10 years, 18 (58.1%) also reported current medication use. For 97 subjects with hypertension, 45 (46.4%) also reported taking medication. Among the 248 subjects who did not report either heart disease or hypertension, only 15(6.0%) used these medications. Medications prescribed for respiratory disease included beta-agonists, cromolyn, ipratropium bromide, inhaled steroids, and theophylline. Of the 51 subjects who reported chronic respiratory disease (asthma or COPD), 20 (39%) were using medications, and of the other 310 subjects without chronic respiratory disease reported, only 10 (3%) reported taking such medications.

Discussion

We assessed factors influencing mortality in chronic SCI over a median of 4.5 years. Overall, mortality rates were elevated by 47%. Risk factors for death included diabetes, heart disease, lower levels of pulmonary function, and current and recent cigarette smoking. Level and extent of SCI, older age at injury, and injury in earlier calendar years were not associated with mortality.

Although overall survival was also reduced in previous chronic SCI mortality studies, differences based on neurological level and completeness of injury were small and in some studies, also not detectable as in the current study.[1–3,5,7] In contrast, in the US Model Systems Database of 17 349 subjects where participants were included in the cohort soon after injury the relative risk (RR) of mortality between 1973 and 1992 for complete motor or ASIA C SCI levels C1–C4 was 5.42 and for SCI levels C5–C8 was 2.72 compared to participants with ASIA D SCI. The mortality risk for participants with complete motor or ASIA C SCI with thoracic level or below was only modestly elevated (RR = 1.53). Differences in mortality based on neurological level and completeness of injury diminished within 5–10 years after injury suggesting that large differences in survival due to ASIA classification are greatest in the years immediately following injury.2 In SCI subjects who had disability claims processed by the DVA between 1940 and 19871 or who survived acute injury and received treatment in a VA hospital between 1955 and 1965,3 survival was reduced to 80–85% of expected rates but was similar, regardless of the level and extent of injury. In a study from Denmark, subjects admitted to a rehabilitation hospital between 1953 and 1990 with mortality assessed through 1992 had no mortality differences based on SCI level, although overall survival was reduced to 90% of expected rates.5 Similarly, among SCI subjects in Great Britian who survived 1-year post injury and entered a regional rehabilitation center, tetraplegics had only a slight increase in mortality compared to paraplegic subjects.7 The small size in the current study may have contributed to the inability to detect significant differences in survival based on ASIA classification. However,

ours and previous observations indicate that it is necessary to consider factors other than SCI level and extent of injury in understanding differences in survival among individuals with chronic SCI who have a period of survival beyond the acute injury.

In previous studies of subjects with chronic SCI from the US,2 Australia,4 Denmark,5 and Great Britain,7 respiratory causes were the most common underlying cause of death. In the Model Systems Uniform Database, respiratory diseases as an underlying cause accounted for 20.4% of the deaths.2 In other studies, respiratory causes as an underlying cause accounted for 16–34% of deaths.4,5,7 Unlike previous studies, respiratory causes more commonly contributed to death in the current study (19% of deaths) but were the underlying cause in only 5.4%. With underlying and contributing causes considered together, the most common causes of death in the current study were circulatory diseases, which were a factor in 40.5% of deaths. Despite the small numbers of deaths, the elevated SMR values for bladder cancer and osteomyelitis are also consistent with past reports noting that subjects with SCI are at increased risk for these conditions.20,21

Heart disease, diabetes, pulmonary function abnormalities, and cigarette smoking were predictors of mortality, and are also known to be determinants of mortality in the able-bodied. Heart disease is the leading cause of death in US men, accounting for approximately 30% of deaths, and diabetes is the sixth leading cause of death.22 Based on Medicare data in men ≥ 65 in 1995, the age-adjusted relative risk of all-cause mortality through 1999 was 1.76 (95% CI = 1.72–1.79) in diabetics compared to those without diabetes.23 Based on followup of 6255 able-bodied subjects examined during the Second National Health and Nutrition Examination Survey between 1976 and 1980, the age, smoking, and gender adjusted risk of all-cause mortality in diabetics through 1992 was 1.97 (95% CI = 1.59–2.43) and in subjects with pre-existing cardiovascular disease was 1.82 (95% CI = 1.44–2.32).24 Similar to the able-bodied, subjects with SCI who had stopped smoking in the distant past had the lowest risk of dying, while mortality among current smokers was dependent on amount smoked.25 Subjects who quit smoking more recently had the greatest risk, suggesting smoking cessation occurred due to illness.25 Lower levels of pulmonary function were also related to increased all-cause mortality, similar to findings observed in the ablebodied. 26–28 These observations illustrate with aging, factors that influence mortality in the able-bodied also are the most important factors influencing mortality in SCI. Owing to the relatively small numbers of deaths, our results are too imprecise to assess whether mortality due to heart disease and diabetes in this study is greater in SCI than in the able-bodied.

We were able to validate self-report of disease in all cases of diabetes, and in a high proportion of subjects with heart disease and hypertension. Few subjects who failed to report either heart disease or a history of hypertension used medications for these conditions upon entry to the study. Although subjects reported a history of doctor-diagnosed obstructive lung disease twice as often as the diagnosis was noted in the medical record, only 3% of subjects without this diagnosis used medications, suggesting some validity to self-report. It is possible that self-report of obstructive lung disease was based on clinical events distant to injury or were not relevant to hospitalization or clinic visits available for review. Misclassification of medical conditions would make it more difficult to detect a true effect of these conditions on mortality, and would underestimate true risk.

A limitation of this study is that only about half of the people eligible for the study participated. Subjects who did not participate may have been too ill to come to the medical center for testing, or conversely, may have been in better health than those studied. Nonparticipation bias based on illness would underestimate the prevalence of underlying diseases and mortality risks and, if healthier persons were excluded, mortality rates would be

overestimated. The extent of bias due to nonparticipation of sicker and possibly older subjects is likely to be small since the effect of age on mortality (8% per year) was similar to results from both the Model Systems Database (6% per year) in which all subjects who survived 24 h were included, and another large study in which subjects who survived 1 year prior to entering a rehabilitation center were included (7% mortality per year).7

Although SCI level and completeness of injury were not directly related to mortality, it is likely that SCI still influences mortality indirectly via the factors identified in the multivariate models. For example, SCI results in respiratory muscle weakness as well as changes in chest wall and lung compliance,29,30 and it is recognized that higher neurological level and greater completeness of injury are associated with lower levels of pulmonary function. Preliminary observations suggest that cigarette smoking leads to a greater than expected accelerated loss of lung function in SCI.31 Also, in SCI abnormalities of carbohydrate metabolism in the setting of weight gain, changes in body muscle mass, and lack of physical activity, can thereby, predispose those with SCI to diabetes and cardiovascular diseases.32–35

The results of this study provide evidence that mortality following SCI is related to treatable or preventable factors. Although this study was not designed to assess the appropriateness of medical therapy, over 40% of subjects with a history of heart disease reported no drug therapy. It is likely that, in SCI, smoking cessation and the early recognition and aggressive management of cardiovascular disease and diabetes, would dramatically reduce the mortality in subjects who have survived the effects of acute injury.

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Table 1

Characteristics of longitudinal cohort

	All subjects	
Variables	***Survivors* (n = *324*)**	***Deceased* (n = *37*)**
Age (years)	48.9± 14.4	65.0± 12.4
Years since SCI	16.7± 12.2	24.2± 16.5
Age at SCI (years)	32.2± 13.6	40.8± 19.2
Calendar year of injury		
1940–1949	7 (2.2%)	5 (13.5%)
1950–1959	20 (6.2%)	5 (13.5%)
1960–1969	34 (10.5%)	5 (13.5%)
1970–1979	91 (28.1%)	8 (21.6%)
1980–1989	85 (26.2%)	7 (18.9%)
1990–	87 (26.9%)	7 (18.9%)
BMI (kg/m^2)	26.3 ± 5.0 (*n* = 323)	26.0± 6.4 (*n* = 37)
Race		
White	302 (93.2%)	35 (94.6%)
Non-white	22 (6.8%)	2 (5.4%)
Cigarette smoking		
Current	94 (29.0%)	9 (24.3%)
All former	126 (39.0%)	21 (56.8%)
≤ 7 years quit	29 (80.6%)	7 (19.4%)
> 7 years quit	97 (87.4%)	14 (12.6%)
Never	104 (32.1%)	7 (18.9%)
Pack-years[a]	30.5 ± 27.4 (*n* = 220)	40.9± 31.4 (*n* = 30)
Non-traumatic injury	21 (6.5%)	7 (18.9%)
SCI motor level		
Complete		
Cervical	69 (21.3%)	6 (16.2%)
High thor. (T1–T4)	48 (14.8%)	4 (10.8%)
Low thor. (T5–T12)	40 (12.4%)	7 (18.9%)
Others	35 (10.8%)	3 (8.1%)
Incomplete		
Cervical ASIA C	35 (10.8%)	6 (16.2%)
Cervical ASIA D	40 (12.4%)	2 (5.4%)
Other ASIA C	25 (7.7%)	6 (16.2%)
Other ASIA D	32 (9.9%)	3 (8.1%)
Pulmonary function		
%-predicted FVC	76.6%± 18.1 (*n* = 312)	67.3%± 18.4 (*n* = 36)
%-predicted FEV_1	76.5%± 18.3 (*n* = 312)	64.6%± 20.5 (*n* = 36)
FEV_1/FVC	0.78± 0.09 (*n* = 318)	0.72± 0.14 (*n* = 36)
MIP (cm H_2O)	88.7± 33.7 (*n* = 316)	64.9± 26.8 (*n* = 36)

	All subjects	
Variables	***Survivors (n = 324)***	***Deceased (n = 37)***
MEP (cm H_2O)	104.4± 50.7 (*n* = 204)	91.0± 39.4 (*n* = 21)
Illnesses[b]		
Heart Disease	19 (5.9%)	12 (32.4%)
Hypertension	79 (24.4%)	18 (48.7%)
Diabetes	27 (8.3%)	9 (24.3%)
Asthma	27 (8.3%)	4 (10.8%)
COPD	26 (8.0%)	4 (10.8%)
Chronic respiratory disease[c]	45 (13.9%)	6 (16.2%)
Symptoms[b]		
Any wheeze	156 (48.2%)	22 (59.5%)
Persistent wheeze	62 (19.1%)	12 (32.4%)
Chronic cough	59 (18.2%)	8 (21.6%)
Chronic phlegm	68 (21.0%)	11 (29.7%)

[a] Pack-years reported for current and former smokers

[b] Please refer to text definitions

[c] Asthma or COPD. For continuous variables, mean ±SD presented

Table 2

SMR by level and extent of injury and selected causes of death

	Observed/expected deaths	*SMR*	*95% CI*
Entire cohort/all deaths	37/25.13	1.47	1.04–2.03
SCI level and extent			
Cervical motor complete	6/3.71	1.62	0.59–3.52
Other motor complete	14/9.92	1.41	0.77–2.37
Cervical ASIA C	6/2.57	2.33	0.85–5.07
Other motor incomplete	11/8.92	1.23	0.61–2.21
Cause of death/ICD-9 code			
All cancers	9/7.0	1.29	0.59–2.45
Bladder cancer and other urinary organs 188, 189.3–189.9	3/0.18	16.41	3.38–47.99
Diabetes 250	2/0.53	3.74	0.45–13.51
Diseases of the heart 390–398, 402, 404, 410–414, 420–429	5/8.45	0.59	0.19–1.38
Other diseases of the circulatory system 401, 403, 405, 415–417, 430–438, 440–459	3/2.01	1.49	0.31–4.36
Diseases of the arteries, veins, and pulmonary circulation 415–417, 440–459	2/1.74	1.15	0.13–4.15
Diseases of the respiratory system 460–466, 470–478, 480–487, 490–519	2/2.36	0.85	0.10–3.06
Diseases of the genitourinary system 580–608, 610, 611	2/0.36	5.56	0.67–20.06
Osteomyelitis and periostitis 730	1/0.0053	187.61	4.74–1042.29

Table 3

Primary and secondary causes of death based on ICD-9 codes

Cause of death/ICD-9 code	*Underlying cause of death*	*Contributing cause of death*	*Totals*
Infectious/parasitic disorders	5.4%	8.1%	13.5%
001–139	2/37	3/37	5/37
Neoplasms	24.3%		24.3%
140–239	9/37	0/37	9/37
Endocrine/metabolic disorders	8.1%	5.4%	13.5%
240–279	3/37	2/37	5/37
Nervous system disorder	8.1%	27.0%	35.1%
320–389	3/37	10/37	13/37
Circulatory system disorder	21.6%	18.9%	40.5%
390–459	8/37	7/37	15/37
Respiratory system disorders	5.4%	18.9%	24.3%
460–519	2/37	7/37	9/37
Gastrointestinal disorders		13.5%	13.5%
520–579	0/37	5/37	5/37
Genitourinary system disorder	5.4%	10.8%	16.2%
580–629	2/37	4/37	6/37
Musculoskeletal system disorders	2.7%		2.7%
710–739	1/37	0/37	1/37
Congenital disorders	2.7%		2.7%
740–759	1/37	0/37	1/37
External	13.5%	5.47%	18.9%
E800–E999	5/37	2/37	7/37
Other/ill-defined conditions	5.4%	35.1%	37.8%
	1/37	13/37	14/37

Table 4

RR of unadjusted and age adjusted predictors of mortality based on proportional hazards model results (n = 361 subjects and 37 deaths unless indicated)

	Unadjusted		*Age Adjusted*	
Variables	***RR***	***95% CI***	***RR***	***95% CI***
Age at entry	1.08	1.05–1.10	–	–
Age at injury	1.04	1.02–1.06	1.00	0.98–1.02
Years post-SCI	1.04	1.03–1.06	1.00	0.98–1.03
Level/completeness				
Motor complete cervical	0.74	0.27–1.99	1.23	0.45–3.37
Cervical ASIA C	1.34	0.50–3.62	1.77	0.65–4.84
Other motor complete	0.84	0.38–1.85	1.07	0.48–2.36
Other motor incomplete	1.00	–	1.00	–
Cause of SCI				
Non-traumatic	3.51	1.54–7.99	1.80	0.77–4.21
Traumatic	1.00	–	1.00	–
Cigarette smoking				
Cigarette/day[a]	1.03	0.99–1.06	1.04	1.01–1.07
Former, ≤ 7 years quit	3.30	1.24–8.79	5.09	1.89–13.70
Former, > 7 years quit	2.24	0.98–5.12	1.29	0.58–2.84
Never smoker	1.00	–	1.00	–
Respiratory symptoms				
Any wheeze	1.54	0.80–2.96	2.38	1.21–4.68
Persistent wheeze	2.06	1.03–4.10	1.87	0.94–3.73
Chronic cough	1.18	0.54–2.58	1.18	0.54–2.57
Chronic phlegm	1.49	0.74–3.02	1.13	0.55–2.33
Comorbid diseases				
Hypertension	2.56	1.34–4.87	1.65	0.86–3.16
Heart disease	5.89	2.96–11.74	3.00	1.47–6.12
Diabetes	3.23	1.52–6.85	2.03	0.95–4.34
Asthma	1.25	0.44–3.53	1.68	0.59–4.79
COPD	1.29	0.46–3.64	1.04	0.37–2.94
Obstructive lung disease	1.13	0.47–2.70	1.16	0.48–2.78
Pulmonary function				
%-Predicted FEV_1[b] (n = 348, 36 deaths)	0.97	0.95–0.99	0.97	0.95–0.99
%-Predicted FVC[b] (n = 348, 36 deaths)	0.97	0.96–0.99	0.97	0.95–0.99
FEV_1/FVC (n = 354, 36 deaths)	0.005	0.00–0.082	0.09	0.004–1.79
MIP (cm H_2O) (n = 352, 36 deaths)	0.98	0.97–0.99	0.99	0.98–1.00
MEP (cm H_2O) (n = 225, 21 deaths)	1.00	0.98–1.01	1.00	0.99–1.01

[a] Relative risk per cigarette per day

[b] Relative risk per %-predicted

Table 5

Multivariate models of mortality

	n = 348 and 36 deaths		n = 361 and 37 deaths	
Variable	***RR***	***95% CI***	***RR***	***95% CI***
Age	1.08	1.05–1.12	1.08	1.05–1.12
Diabetes	2.65	1.21–5.83	2.62	1.19–5.77
Heart disease	3.64	1.65–8.02	3.66	1.73–7.78
Cigarettes per day[a]	1.04	1.01–1.08	1.05	1.02–1.08
Former, ≤ 7 years quit	3.53	1.27–9.79	4.20	1.56–11.26
Former, > 7 years quit	1.01	0.42–2.41	1.00	0.44–2.25
%-predicted FEV_1[b]	0.97	0.95–0.99		

[a] Relative risk per cigarette per day

[b] Relative risk per %-predicted