Spinal Cord (2000) 38, 604–610

www.nature.com/sc

Causes of death after spinal cord injury

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Study design: Mortality review was undertaken of patients who suffered traumatic spinal cord injury (SCI) between 1955 and 1994 inclusive.
Objectives: The study objective was to provide evidence of reasons for the observed reduction in long-term life expectancy for the SCI population.
Setting: Patients were those who had most, if not all, of their inpatient and outpatient care at Royal North Shore Hospital, Spinal Injuries Unit, Sydney, New South Wales, Australia.
Methods: Data on causes of death for 195 patients fitting the inclusion criteria were analysed by actuarial methods using ICD9CM classifications.
Results: The incidence of death in the spinal cord injured, from septicaemia, pneumonia and influenza, diseases of the urinary uystem and suicide, are significantly higher than in the general population. The findings confirm variations in potentially treatable causes of death depending on neurological impairment, attained age and duration since injury. Unlike septicaemia and pneumonia, which have shown a significant reduction since 1980, the death rate for suicide alone has risen.
Conclusion: This analysis identified complications which affect mortality and morbidity in patients suffering from the effects of SCI.
Spinal Cord (2000) **38,** 604–610

Keywords: spinal cord injury; causes of death; septicaemia; respiratory tract infection; renal failure; suicide

Introduction

Studies over the past decade have revealed that, with improved management of the neuropathic bladder, urinary tract complications and renal failure are no longer the leading causes of death in the spinal cord injured (SCI) population.[1–4] Among the leading causes of death in these studies were pneumonia, septicaemia, heart disease and suicide, although the frequency of each varied considerably in tetraplegia and paraplegia. Another leading cause of death early after injury was pulmonary embolism.[1,3] Whiteneck *et al* [2] studied a group of 834 individuals with spinal cord injury for 20 years or more who had been admitted to one of two specialised centres within 1 year of initial injury. Genitourinary disorders accounted for 43% of deaths occurring in the 1940's and 1950's, but only 10% of deaths occurring in the 1980's and 1990's, while cardiovascular and respiratory deaths became relatively more frequent.

Rish *et al* [5] studied mortality in a cohort of 230 Vietnam veterans who had significant myelopathy and survived 72 h beyond triage. In this group who had previous excellent health (active duty military service), the most frequent cause of death was sepsis. Suicide among paraplegics occurred at a rate of 10 times that reported for uninjured peers. After 5 years, survival approached but never reached the rate established for uninjured peers.

In a recent study,[6] the authors examined life expectancy after spinal cord injury having carried out a cumulative survival analysis in patients admitted to a specialised Spinal Unit over a 40 year period. Results showed that the projected mean life expectancy of SCI people compared to that of the whole population approached 70% of normal for the individual with complete tetraplegia and 86% of normal for complete paraplegia (Frankel Grade A). Patients with an incomplete lesion and motor functional capabilities (Frankel Grade D) were projected to have a life expectancy of at least 92% of the normal population. In examining specific causes of death, the current study is complementary to the former study as it seeks to provide explanations for the observed reductions in life expectancy for different groups of SCI individuals.

De Vivo and colleagues[1,3,4] have previously reported high mortality rates for the first post injury year. In this current study, only deaths that occurred at least 18 months after injury were considered in order to exclude deaths occurring in the acute and sub-acute phases of injury, frequently as a result of multiple injuries and/or high cervical SCI. Knowledge of survival outcomes and specific causes of death in the medium to longer term following injury will help guide

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decisions in medical management and allow appropriate preventative strategies to be emphasised.

Aims

The aims of the study were twofold: (1) To analyse causes of death amongst a cohort of SCI individuals by attained age, duration since injury and neurological impairment against those of the normal population. (2) To examine and compare the causes of death prior to and since 1980.

Method

Data for the study population were drawn from a cohort of 335 individuals with traumatic SCI who were known to have died and been entered into an active Spinal Unit patient database (Access software). This active usage contributes to the small difference of six additional deaths in the present dataset from the cohort described in the previously published life expectancy study.[6] Inclusion criteria required that individuals had resided in NSW and had an identifiable cause of death and, if available, a secondary cause of death, confirmed by either a death certificate, coroner's or post mortem report, or a discharge summary in the medical records. Death occurred within 18 months of injury in 132 patients, while in a further eight cases insufficient information was available regarding time after injury when death had occurred. One hundred and ninety-five deceased patients remained as suitable for inclusion in this study. Patients were grouped into paraplegia and tetraplegia, complete or incomplete. Further division into Frankel classification was not possible due to insufficient numbers for meaningful analysis.

For reliability, one medical officer only reviewed the available information to determine cause of death. In many instances a secondary or contributory cause of death was cited. It was acknowledged that deaths in spinal cord injured individuals were often multifactorial and where multiple pathology existed, a decision was made by the medical officer as to the most likely major factor in the death given all available information. ICD9CM (International Classification of Diseases – 9th Edition Clinical Modification) groupings were used to classify diseases causing death.

Similar actuarial methods to those described in our previous study[6] were used to compare findings with those of the normal population. Standardised Mortality Ratios (SMR's) were calculated by applying the age and sex adjusted rates for the community to the spinal cord injured exposed to risk to give a ratio of the observed to the expected number of deaths. The differences in SMR between the period prior to 1980 and the period from 1980 onwards were calculated as the differences between the sample means. The populations were assumed to be normally distributed, with the variance of the differences taken as the sum of the individual variances.

Confidence intervals at the 95% level were also calculated to assist interpretation of data. For very small sample sizes, the results are less meaningful – in these cases the assumption of normality led to a necessity to set lower confidence limits for SMR at zero.

Results

Categorised causes of death for the study population are shown in Table 1. The leading causes of death in established SCI patients across all ages were pneumonia and influenza ($n=27$), septicaemia ($n=25$), cancer ($n=24$), ischaemic heart diseases (IHD) ($n=21$), diseases of the urinary system ($n=18$) and suicide ($n=15$). Significant elevations of SMR associated with large numbers of actual deaths occurred in septicaemia (SMR = 172.3), pneumonia and influenza (SMR = 32.5), diseases of the urinary system (SMR = 22.8), suicide (SMR = 4.4) and cerebrovascular disease (SMR = 2.3). From the total of 195 actual deaths, only 85 were to be expected from the general population, yielding an SMR of 2.3 (95% C.I. 2.0–2.6) overall.

The SMRs for ischaemic heart disease (0.9) and for cancer (1.0) indicated that there was very little difference between the observed and the expected number of deaths among these causes which approximated those of the general population.

Causes of death by attained age (Table 2) showed elevated SMR's for septicaemia, diseases of the urinary tract and pneumonia and influenza in each age bracket. Deaths due to septicaemia increased with age and very high SMR's were noted across each age bracket. In the suicide group, most deaths occurred in the youngest group (0–39 years) with a SMR five times greater than normal population. There were considerably fewer deaths due to suicide between 40–59 years (SMR = 3.8, C.I. = 0.1–7.5) and there were no known suicides in the 60+ years group. For pneumonia and influenza and diseases of the urinary system the calculated SMR's, although elevated across all age groups, appeared to reduce substantially with age attained.

Review of duration since injury (Table 3) showed markedly elevated SMR's for septicaemia and pneumonia and influenza at each grouping, with the greatest number of deaths occurring between 6–19 years post injury. In addition, increased deaths and elevated SMR's were also evident for diseases of the urinary system in the 6–19 years post injury bracket and suicide in the 1.5–5 years post injury bracket. Small numbers in other groupings led to unstable estimates for calculated values.

In the tetraplegic subgroups, (Table 4a) patients with complete lesions were more likely to die of septicaemia, pneumonia and influenza and urinary related diseases than those with incomplete lesions, whilst in paraplegia (Table 4b) this was only true for septicaemia. Death due to septicaemia and in particular pneumonia and influenza occurred far

Table 1 Cause of death of 195 deceased persons with spinal cord injury

Causes of death	*Actual deaths*	*SMR*	*SMR 95% limits*
Septicaemia (038)	25	172.3	104.8–239.7
Cancer (140–239)	24	1.0	0.6–1.4
Diseases of the nervous system (320–359)	6	4.9	1.0–8.8
Ischaemic heart disease (410–414)	21	0.9	0.9–1.3
Diseases of the pulmonary circulation (415–417)	4	26.2	0.5–51.9
Nonischaemic heart disease (420–429)	7	2.2	0.6–3.8
Cerebrovascular disease (430–438)	14	2.3	1.1–3.5
Diseases of the artery (440–448)	4	2.2	0.0–4.5
Pneumonia and influenza (480–487)	27	32.5	20.3–44.8
Other respiratory diseases (460–478) (490–519)	5	1.0	0.1–1.9
Diseases of the digestive system (520–579)	3	1.0	0.0–2.0
Diseases of the urinary system (580–599)	18	22.8	12.3–33.4
Symptoms and ill defined conditions (780–799)	4	19.7	0.4–38.9
Unintentional injuries (E800–E949)	5	0.7	0.1–1.4
Suicide (E950–E959)	15	4.4	2.2–6.6
All other external (E980–E999)	1	1.6	0.0–4.7
Unknown	12	2.4	1.0–3.7

ICD9CM Codes are in parentheses

Table 2 Attained age

	0–39 years			*40– 59 years*			*60 years+*		
Causes of death	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*
Septicaemia	2	159.2	61.4–379.8	9	309.2	107.4–511.1	14	135.1	64.7–205.6
Pneumonia & influenza	9	143.3	49.7–236.8	9	58.0	20.1–95.8	9	14.7	5.1–24.3
Diseases of the urinary system	5	159.7	19.8–299.7	3	24.6	3.2–52.4	10	15.7	6.0–25.5
Suicide	11	5.4	2.2–8.6	4	3.8	0.1–7.5	0	0	n/a

(Only groups with elevated SMR's presented)

Table 3 Duration since injury

	1.5–5 years			*6–19 years*			*20–29 years*		
Causes of death	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*
Septicaemia	4	124.1	2.5–245.6	13	144.1	65.8–222.4	7	452.9	118.1–787.6
Pneumonia & influenza	8	41.0	12.6–69.4	13	25.2	11.5–39.0	5	60.7	7.6–113.8
Diseases of the urinary system	4	21.4	0.4–42.3	12	24.8	10.8–38.8	2	25.9	0.0–61.7
Suicide	6	6.8	1.4–12.3	6	2.8	0.6–5.0	2	9.1	0.0–19.5

(Only groups with elevated SMR's presented)

Table 4a Neurological impairment–tetraplegia

	Incomplete			*Complete*			*All*		
Causes of death	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*
Septicaemia	3	55.8	0.0–119.0	13	546.6	249.9–843.2	16	206.4	105.4–307.5
Pneumonia & influenza	3	9.4	0.0–20.1	19	143.4	79.1–207.8	22	48.8	28.4–69.1
Diseases of the urinary system	1	3.2	0.0–9.5	5	42.3	5.2–79.4	6	13.9	2.8–25.1
Suicide	1	3.8	0.0–8.2	7	7.8	2.0–13.6	10	6.0	2.3–9.7

(Only groups with elevated SMR's presented)

more frequently in the tetraplegic than paraplegic group.

Death by time of injury (Table 5a,b) showed substantially elevated SMR's for septicaemia and pneumonia and influenza where each was about 30% of the estimate prior to 1980. Difference pre and post 1980 was 139.5 for septicaemia ($P=0.030$ (2 sided test), $P=0.015$ (1 sided test) and for pneumonia and influenza was 31.2 ($P=0.007$ (2 sided test), $P=0.004$ (1 sided test)). In the case of the urinary system, there was a difference of 14.0 ($P=0.177$ (2 sided test), $P=0.089$ (1 sided test)). The ratio for suicide showed an increase with a difference of -6.2 ($P=0.044$ (2 sided test), $P=0.022$ (1 sided test)).

For the 25 cases where the primary cause of death was reported as septicaemia, 37 secondary causes of death were specified on death certificates (Table 6). The most common sources of infection were the urinary tract (30%), pressure areas (19%), respiratory tract (14%) and bowels (11%). Cellulitis and gas gangrene each occurred once as a secondary cause in the death certificates listing septicaemia as the primary cause of death.

In the tabulation of method of suicide (Table 7), it is evident that suicide occurred more commonly in tetraplegia than paraplegia. The most common method chosen was by drowning, with all these occurring in tetraplegic individuals who presumably were unable to use any other unassisted methods. It is usually observed in the living population of spinal cord injured that the ratio of females to males is 1 in 3 to 4, however in this group deaths occurred in a reduced ratio of 1 in 5 suggesting that proportionately less females died prematurely than amongst the males.

Discussion

The higher than normal incidence of premature deaths in the spinal cord injured population, and in particular septicaemia, pneumonia, urinary tract disease leading to renal failure, and suicide, indicate the necessity for continued vigilance with regular clinical follow up as well as development of more targeted strategies for prevention of increasing morbidity and mortality. This is highlighted by results from the current study where deaths in the younger age group (less than 40 years)

Table 4b Neurological impairment – paraplegia

	Incomplete			*Complete*			*All*		
Causes of death	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*
Septicaemia	1	47.3	0.0 – 139.9	8	172.2	52.9 – 291.4	9	133.1	46.2 – 220.0
Pneumonia & influenza	1	8.6	0.0 – 25.2	4	15.2	0.5 – 30.2	5	13.2	1.6 – 24.8
Diseases of the urinary system	3	26.9	0.0 – 57.4	9	36.5	12.7 – 60.4	12	33.5	14.6 – 52.5

(Only groups with elevated SMR's presented)

Table 5a Date of injury

	Prior to 1980			*Since 1980*		
Causes of death	*Actual deaths*	*SMR*	*SMR 95% limits*	*Actual deaths*	*SMR*	*SMR 95% limits*
Septicaemia	20	227.0	127.36 – 326.4	5	87.5	10.8 – 164.1
Pneumonia & influenza	22	45.6	26.6 – 64.7	5	14.4	1.8 – 26.9
Diseases of the urinary system	13	28.8	13.1 – 44.4	5	14.8	1.8 – 27.8
Suicide	6	2.5	0.5 – 4.5	9	8.7	3.0 – 14.4

(Only groups with elevated SMR's presented)

Table 5b Date of injury. Difference between prior to 1980 and since 1980

Causes of death	*Difference*	*S.D.*	*95% C.L.*	*Two-sided test P*	*One-sided test P*
Septicaemia	139.5	641	13.9 – 265.1	0.030	0.015
Pneumonia & influenza	31.2	11.6	8.4 – 54.0	0.007	0.004
Diseases of the urinary system	14.0	10.4	6.3 – 34.3	0.177	0.089
Suicide	-6.2	3.1	-12.2 – -0.2	0.044	0.022

Assumptions: That the data is distributed normally and the standard deviation can be estimated from the existing confidence intervals by dividing (SMR-LCI%95) by 1.96. (Only groups with elevated SMR's presented). (The negative values are appropriate as they are estimates of a difference)

due to pneumonia and influenza, diseases of the urinary system and suicide were substantially greater than the number expected in the normal population. In regard to septicaemia this greater than expected number of deaths was evident across all age brackets.

Septicaemia had a particularly high SMR in middle age (40 – 59 years group) which could be reflecting patients with paraplegia or tetraplegia for more than 20 years and complications of a neurogenic bladder. In both paraplegia and tetraplegia motor complete lesions were far more likely to result in earlier death due to septicaemia or diseases of the urinary system. It is hardly surprising that the presence of preserved sensation or useful motor function is protective, however, the clear effect of attained age on death rates from the causes also suggests the possible influence of functional deterioration with ageing on survival in patients with complete lesions. For pneumonia and influenza in the tetraplegia group, the degree of neurological impairment or completeness was the key factor rather than age, as could be anticipated due to impaired cough, reduced vital capacity and respiratory reserve. Consistent with previous findings by De Vivo[4], pneumonia and influenza was the leading cause of death in this study. The recommendation that is necessary for tetraplegics and high paraplegics to curtail their smoking habits in order to avoid respiratory complications is unquestionable and this should be an addition to the usual public health warnings regarding tobacco use. Results from this current study suggest that awareness and proactive respiratory management in more recent years has reduced deaths due to pneumonia and influenza; falling to 32% of rate prior to 1980. De Vivo *et al* [4] concluded that increased clinical attention and research should now be focused on the respiratory system in a similar fashion to the way that close attention to urinary tract management in the past had been responsible for dramatic reductions in mortality.

The finding that the urinary complications leading to deaths has fallen, with reduction of SMR for urinary system disease by almost half in the comparison pre-1980 and since, is consistent with the findings of others.[2,4] Samsa *et al*[7] reviewed a large cohort of 5545 male veterans with traumatic SCI who survived at least 3 months after injury. It was found that the pattern of cause of death began approaching that of the general population, but causes associated with long-term sequelae of SCI (eg septicaemia or renal failure) continued to effect the SCI group disproportionately. By 20 years after injury, causes of death in SCI veterans and the general population were more noteworthy because of their similarities. Of note in this current study, however, was that when the secondary causes of death were examined for the septicaemia group (see Table 6), the urinary system was still the most frequent underlying cause of death, with SMR remaining high in patients 20 – 29 years since injury. Therefore SCI patients, especially established patients, still remain at risk due to ongoing urinary complications, especially septicaemia.

Table 6 Secondary causes where death due to septicaemia

Causes	*Number*
Urinary tract	11
Pressure areas	7
Respiratory tract	5
Strangulated bowel	3
Gangrene of the leg	2
Meningitis	2
Digestive tract	1
Gas gangrene	1
Obstruction of ileal conduit	1
Cellulitis	1
Ischaemic heart disease	1
Brain stem CVA	1
Chronic lymphatic leukaemia	1
Total	37

Table 7 Method of suicide

	Paraplegia	*Tetraplegia*	*All*
Gunshot to head	2	1	3
Overdose	1	2	3
CO poisoning		2	2
Drowning		5	5
Hanging	1		1
Unknown	1		1
Total	5	10	15

It is reasonable to postulate that SCI patients could suffer death due to neoplasm more frequently due to late or occult presentations caused by lack of or altered sensation delaying detection or limiting success with curative surgical and medical treatment. However, our findings showed that the number of deaths due to neoplasm was no greater than in the general population. It is notable that, of the 25 deaths due to neoplasm in the current study, five (20%) were caused by lung cancer. In the state of NSW, Australia, lung cancer is the leading cause of cancer deaths in males over the whole population (24.1%) and the second leading neoplastic cause of death in the whole female population (13.7%). In this present study, only one patient died of carcinoma of the bladder, suggesting that SCI patients do not have an increased incidence of carcinoma of the bladder. A recent publication[8] has reported an increased risk of bladder malignancy in SCI patients with indwelling catheters.

Cerebrovascular disease caused death at approximately twice the rate expected in the normal population (SMR = 2.3), which was similar to previous findings by De Vivo and Stover where a SMR of 2.2 was found.[4] These values being small in comparison to the other causes. In regard to cardiovascular disease, similar findings were also

shown to those demonstrated by DeVivo and Stover, where despite the apparent high number of smokers amongst the SCI population and the sedentary nature of their disability, the rate of death due to cardiovascular disease approximated that of the general population.

Disturbingly, however, in the case of suicide, the rate is not only considerably higher than the normal population accounting for 15 out of 195 deaths in this study, but exhibits an increasing trend which has more than trebled since 1980, unlike other major causes of death. This study again highlights the fact that spinal cord injury places individuals at considerable risk of suicide compared to the general population. The overall SMR for suicide of 4.4 with most deaths occurring in the younger age group was consistent with previous studies,[9,10,11] although unlike these other studies less than half the deaths occurred in the first 5 years after injury. Results showing individuals with tetraplegia to be at greater risk than those with paraplegia supported the findings of several previous studies[9,10,12] whilst contradicting others.[4,11] Charlifue and Gerhart[12] have suggested that many of the risk factors for suicide such as alcohol and drug abuse, premorbid psychiatric illness, previous suicide attempts and family disintegration are not specific to SCI population, but pertain to general population as a whole. The increasing trend in rates of suicide in recent years has also been reported in other studies[13,14] and calls for better screening measures early after injury and during rehabilitation to identify individuals at increased risk, who require greater psychological support and more intensive follow up in the community. Three deaths due to suicide occurred very late (20–29 years since injury) with a SMR of 9.1. (0.0–19.5). This is also of interest because it may reflect difficulty for previously fiercely independent individuals coping with an increased level of disability and dependence with ageing, for instance due to rotator cuff pathology, where for these individuals it is like being acutely injured again with their self-image destroyed.

Limitations of this current study include the possibility of some bias due to a number of patients being excluded because the date of death was unavailable to calculate SMR. The effect of such a small number of cases in this category ($\sim$4%) on statistical outcomes is believed negligible. There were a greater number of cases for which there was insufficient information ($\sim$6%) to classify deaths due to inadequate descriptions on death certificates, no autopsy or medical records data, or only information from the National Death Register which did not provide cause of death. These data, however, were included in calculation of the confidence intervals. In addition, information from death certificates regarding secondary or contributory causes of death was also lacking in some cases. Methodological difficulties and resultant limitations in the accuracy and reliability of this type of data from a retrospective cohort are well acknowleged.[4] It is likely these cases have caused underestimation of the SMR's for each cause of death. A further limitation is that the accuracy and reliability of death certificates may be questioned. They are likely to be less accurate than post-mortem reports, but in many cases are the best available record of pathology in these patients.

Conclusion

This report considers the deaths of patients at least 18 months after spinal cord injury. The major preventable causes of death still to be contended with in clinical practice are septicaemia, respiratory tract infection, diseases of the urinary system and suicide. These causes of death occur at a variable rate related to level and severity of permanent paraplegia or tetraplegia, attained age and time since injury. While it is shown that the rate of deaths due to septicaemia, pneumonia and influenza and diseases of the urinary system have been reduced, in the case of suicide there has been a demonstrable increase. Further research and understanding are required in this area to achieve more prompt and appropriate control of risk factors and allow more assistance and allocation of resources to at-risk patients in remediable circumstances.

Acknowledgements

We wish to acknowledge and thank the Spinal Unit Departmental Secretary, Gudrun Hofmann, for her assistance in the compilation of this paper.

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