Survival After Spinal Cord Injury in Australia

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ABSTRACT. O'Connor PJ. Survival after spinal cord injury in Australia. Arch Phys Med Rehabil 2005;86:37-47.

Objective: To assess survival after spinal cord injury (SCI) in Australia.

Design: Cohort study of incident cases from 1986 to 1997, with follow-up to the end of 1998.

Setting: Cases registered by 6 Australian treatment centers for the acute care and rehabilitation of SCI patients.

Participants: Subjects (N=2892), age 15 years and older, from a national population-based SCI register.

Interventions: Not applicable.

Main Outcome Measures: Cumulative and relative survival proportions and hazard ratios.

Results: The all-cases cumulative survival proportion was 94% at 1 year and 86% at 10 years; the relative survival proportions were 95% and 92%, respectively. Significant predictors of survival were: age at injury, sex, neurologic level, and extent of lesion. Cox regression modeling revealed a statistically significant reduction in the 2-month (36% reduction, $P=.01$) and 1-year (27% reduction, $P=.04$) hazard ratio from 1986 to 1991 to 1992 to 1997. Benchmarking analysis revealed no statistically significant difference in survival experience between the 6 spinal treatment units.

Conclusions: Further improvement in survival rates can be achieved through better understanding of the predictors, temporal patterns, and causes of death, and by benchmarking. Early deaths have an important impact on overall survival rates, and warrant further study. International standardization of methods is strongly recommended.

Key Words: Cumulative survival rate; Proportional hazards models; Rehabilitation; Spinal cord injuries; Survival.

ACCURATE AND UP-TO-DATE information on survival after spinal cord injury (SCI) is required for a multitude of purposes, including life planning by the injured person, assessment of financial needs, and service planning.

The Australian Spinal Cord Injury Register (ASCIR) covers all new cases of SCI arising from trauma in persons aged 15 years and over in a current national population of nearly 16 million in this age group.[1] With nearly 3000 cases registered between 1986 and 1997, the ASCIR is the largest national population-based SCI register in the world. Linkage of the ASCIR with the national deaths index (NDI) maintained by the Australian Institute of Health and Welfare[2] (AIHW) provides an opportunity for the first assessment of survival in a national population.

There has been only 1 other SCI survival study[3] in the world based on a national SCI population, but that study was restricted to veterans. There have been 2 previous studies[4,5] of survival from SCI conducted in Australia. Unfortunately, neither was based on a defined population. It was therefore difficult to extrapolate from their findings. Furthermore, many of the cases included in those other studies[6-11] involved subjects injured many years ago and, given the rapid advances in medical care and life expectancy, the significance of the findings might be degraded. The SCI population in this study was injured more recently than the reported populations in other studies internationally, reflecting current survival experience.

This study addressed several questions about survival after SCI in Australia and elsewhere: (1) What is the current survival experience of this population and how does it compare with survival in the general population? (2) How has survival changed over time? (3) What are the predictors of survival? (4) How does survival experience in Australia compare with experience overseas? and (5) How can survival rates be further improved?

METHODS

Australian Spinal Cord Injury Register

The methods of the ASCIR are summarized below and described in detail elsewhere.[12] In Australia, all new cases of SCI are referred to 1 of 6 specialist treatment units, either immediately or after stabilization at another hospital. New cases occurring since 1986 have been registered with the ASCIR by the spinal treatment units.

To facilitate national and international comparisons, the case definition adopted for registration of traumatic cases was the US Center for Disease Control and Prevention clinical definition: "A case of spinal cord injury is defined as the occurrence of an acute, traumatic lesion of neural elements in the spinal canal (spinal cord and cauda equina), resulting in temporary or permanent sensory deficit, motor deficit, or bladder/bowel dysfunction."[13(p11-3)] The ASCIR data dictionary was developed to maximize the potential for international comparisons with data items selected, as much as possible, on the basis of international standards. Neurologic status was coded according to the data standards of the American Spinal Injury Association[14,15] (ASIA).

The extent to which cases of SCI were registered with the ASCIR was assessed on the basis of circumstantial and empirical evidence. It was known that children were generally managed in pediatric hospitals, were few in number, and were mostly excluded from the register. Consequently, coverage was assessed in people aged 15 years and over. If there were cases of SCI treated outside the spinal treatment units, it was highly likely that some would come to the attention of the units at some stage to take advantage of the specialist care offered at the treatment units. A case note review[12] of more than 1000 cases admitted to spinal units failed to identify any that were not referred to a unit, either immediately or after stabilization elsewhere, which suggests that treatment outside the units has not occurred or is rare. This issue was further examined in an

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empirical study comparing case numbers of the ASCIR with those reported from a state-wide data system covering all hospitalizations. The study[16] showed very strong comparability in the number of SCI cases overall, and also by time and age group, further reinforcing the view of complete coverage of the ASCIR.

Quality assurance processes have ensured that the ASCIR data are of high quality overall[12,16] and appropriate for the analysis and conclusions made in this study. Importantly, recent change in the ASIA classification of neurologic status has been shown to have no detrimental impact on the comparability of data over time.[17]

Case Selection

Cases fitting the following criteria were selected from the ASCIR (N=2892): new trauma cases, excluding cases arising from iatrogenic and comiogenic causes; resident in Australia and sustained SCI in Australia; a neurologic deficit at discharge (neurologic level and extent of lesion were recorded at discharge unless there was no change from admission); injury between January 1, 1986, and December 31, 1997, and based on details available at the time of study; and age of 15 years and over at time of injury.

Survival Analysis

In addition to personal identifiers, the ASCIR includes date of death when known. The ASCIR is linked to the NDI by use of personal identifiers and other data included in the register. These procedures are specified in detail in an NDI manual.[2] The NDI is maintained by the AIHW on the basis of information provided by the registrars of birth, deaths, and marriages in each state and territory. The NDI contains data on all deaths in Australia since 1980. It has been extensively used and verified in various survival studies, including survival from cancer,[18,19] work-related diseases,[20] and diseases of veterans.[21]

The initial matching between the register and the NDI was undertaken by the AIHW in Canberra, using a probabilistic record linkage software package called Automatch, developed by Jaro,[22,23] and based on the formal mathematical foundations of Felligi and Sunter.[24] Date of death, where available in the ASCIR, is used by the AIHW as a primary linkage variable and all of these deaths were found in the NDI. The final matching was undertaken manually, following the procedures described below, to ensure accuracy and was verified through independent analysis against a related data set.

In the initial matching, an algorithm was used to allocate scores to each matching pair, with higher scores reflecting a greater probability of a correct match and lower scores a less likely match. To improve the accuracy of the matching and to account for variations in the spelling of surnames (eg, Brown vs Browne), 2 phonetic codes were added to the register and NDI (ie, New York State Intelligence Information System [NYSIIS] and Soundex codes).[25] Despite the differences in the sample surnames, the phonetic codes are identical (NYSIIS=BROAN, Soundex=B65) and therefore allowed the case to be matched on this phonetic code in combination with other variables. An alternative first name was also added to the register to deal with variations in first names, for example, Robert and Bob, Tony and Anthony. The NDI data from some states and territories for some periods do not have date of birth, but an estimated year of birth was calculated from the year of death and age at death. This calculation could have resulted in the estimated year of birth being up to 1 year out in either direction. This lack of precision for some jurisdictions for some periods reduced the certainty of the match between the register and the NDI. These matching pairs were kept separate from those that had a date of birth on both data files and were manually assessed more critically.

After the initial matching process, all matched pairs were manually examined with procedures commonly applied in other Australian survival studies.[19,21] Pairs with an exact match of surname, first name, middle name, sex, date of birth, state of residence, and date of death were accepted as true matches. Other pairs were critically examined with respect to the following: (1) similarity of name, name combinations, and name rarity; (2) plausibility of death linkage, for example, diagnosis date or last contact date was earlier than death date; (3) plausibility of cause of death and SCI diagnosis, including where necessary further assessment of hospital records by spinal unit staff to relate the cause of death to preexisting diagnoses and other details noted on those records; (4) absence of more than 1 such person on the Australian Electoral Roll (to exclude the possibility that there was more than 1 resident having the same combination of name and date of birth); (5) verification that such a person was the only person born in Australia; and (6) follow-up, by spinal unit staff, of SCI cases transferred to other health care facilities (eg, nursing homes) to verify that the person had died.

Three hundred thirty-eight of the matched pairs were accepted as true matches. To check on the completeness of coverage of actual SCI deaths, the accepted true matches were compared with those separately identified by the Royal North Shore Hospital (RNSH) in a study of SCI survival in New South Wales[4] (NSW), and by a crosscheck against the electoral roll. Of 72 NSW deaths identified using the NDI and clerical examination, 41 (57%) were verified by the RNSH study, but 31 (43%) were not. Based on an examination of the RNSH medical records electronic data, card records on ward and departmental records, 16 were further verified as being dead. Thirteen of the remaining 15 cases were confirmed dead according to the Australian Electoral Roll, and the remaining 2 cases were recorded as "no longer on the electoral roll," indicating that they were deaths that had not yet been reported to the Electoral Commission. Therefore, the NDI matching process was independently verified, suggesting complete coverage. Furthermore, because the NDI identified all of the deaths of ASCIR registered cases separately identified by the RNSH study, the sensitivity of the NDI matching process was very high.

Survival was monitored up to December 31, 1998. Basic data description and analysis, as well as Cox regression modeling, was undertaken using the Statistical Package for the Social Sciences.[a]

Before detailed analysis of the data was done, its quality was assessed using DfBeta plots to identify any outlier values. A small number of outliers were detected, checked with reference to the case registration forms, and any errors corrected. Colinearity was assessed using the Condition Index, which, having a value of 14 for the 17 factor comparisons involved, was considered acceptable based on the general advice of Belsley et al,[26] which was informed through experiments and simulation studies.

The analysis of survival and relative survival was undertaken using software developed by the Finnish Cancer Registry,[27-29] and widely used in survival studies throughout the world. The software is cited in more than 140 articles found in the Science Citation Index[30] and the Social Science Citation Index.[31] The theoretical background and terminology of these methods is described in Ederer et al,[32] Hakulinen and Abeywickrama,[29] and Voutilainen et al.[27] Hakulinen's method[28,29] was used to calculate the relative survival proportion. A discussion of the merits of this method compared with alternatives (Ederer I and

Table 1: Case Description, Univariate, and Multivariate Assessment of Hazard Ratios (HR) Using Cox Proportional Hazards Regression

			Univariate Results		Multivariate Results*	
Variable	Cases	Deaths	HR	±95% CI	HR	±95% CI
Age at injury (y)						
15–24	985	52	1.00	Referent	1.00	Referent
25–34	715	32	0.87	0.56–1.35	0.91	0.58–1.42
35–44	434	29	1.34	0.85–2.12	1.43	0.91–2.25
45–54	283	37	2.74	1.80–4.18	3.26	2.13–5.00
55–64	174	40	5.04	3.34–7.62	5.91	3.89–8.97
65–74	176	69	10.80	7.52–15.52	12.41	8.57–17.96
75+	125	79	20.80	14.60–29.63	29.34	20.10–42.83
Gender						
Female	577	64	1.00	Referent	1.00	Referent
Male	2315	274	1.07	0.82–1.41	1.40	1.06–1.85
Cause						
Transport	1449	145	1.00	Referent	Excluded	Excluded
Fall	819	152	2.07	1.65–2.60	Excluded	Excluded
Other	624	41	0.67	0.47–0.94	Excluded	Excluded
Neurologic level						
T1-S5	1355	92	1.00	Referent	1.00	Referent
C1-4	470	105	3.75	2.83–4.96	2.76	2.06–3.70
C5-8	1067	141	2.00	1.54–2.61	1.71	1.31–2.24
Extent						
Incomplete	1748	179	1.00	Referent	1.00	Referent
Complete	1144	159	1.36	1.10–1.68	2.87	2.27–3.63

NOTE. The table shows hazard ratios, not odds ratios, so hazard ratios cannot be calculated from the case and death numbers.
Abbreviation: CI, confidence interval.
*Final model results shown, excluding cause and spinal unit.

Ederer II) is presented by Voutilainen[27] and Esteve[33] and colleagues.

An assessment of survival for ventilator-dependent tetraplegic patients could not be effectively implemented, partly because of the lack of a common definition of this group among spinal units, and because of difficulties with retrospective data capture.

RESULTS

Case Description and Preliminary Analysis

The analysis was based on 2892 SCI patients, 338 of whom died. Most of the subjects were under 45 years of age, were male, suffered injury as a result of a transportation accident, were paraplegic, and had incomplete neurologic damage (table 1). Half of the deaths (n=168) occurred in the first year after SCI, with nearly two thirds of these deaths (n=110) occurring in the first 2 months.

The all-cases analysis revealed a cumulative survival proportion of 94.26% (95% confidence interval [CI], ±.87%) at 1 year and 85.67% (95% CI, ±1.60%) at 10 years (fig 1, table 2). The greatest reduction in the cumulative survival proportion occurred in the first year, particularly within the first 2 months.

Predictors of Survival

Modeling of survival was undertaken using Cox regression. In a univariate assessment, 1 variable at a time, there was a statistically significant difference in survival between categories, relative to the reference group, for age at injury, cause, neurologic level, and extent of lesion. Notable was the substantially higher hazard ratio associated with older age at injury, high cervical injury, and falls. There was no statistically significant difference in survival on the basis of spinal treatment unit.

Multivariate assessment of survival was undertaken following the general advice on modeling of Collett,[34] first involving entry and removal of 1 variable at a time and then combined entry and selective deletion of variables. In addition, automatic forward selection and backward elimination routines were utilized qualitatively. Decisions were also made with reference to the SCI survival literature.[3,7,8,35-42]

When other variables were controlled for in the analysis, one at a time and then combined, the hazard ratios for age at injury, neurologic level, and extent of lesion remained significant, the

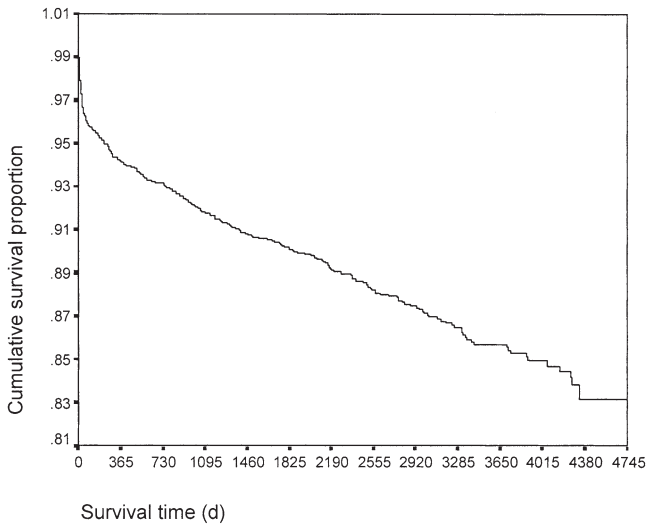

Fig 1. Survival function for all cases, Kaplan-Meier curve.

Table 2: One-Year and 10-Year Cumulative Survival Proportion (CSP) and Relative Survival Proportion (RSP), Single Variable Assessment

	1-Year Survival				10-Year Survival			
Variable	CSP	±95% CI	RSP	±95% CI	CSP	±95% CI	RSP	±95% CI
All cases	.943	.009	.950	.009	.857	.016	.921	.017
Age at injury (y)								
15–24	.976	.010	.977	.010	.939	.018	.949	.018
25–34	.979	.011	.980	.011	.940	.024	.952	.024
35–44	.979	.014	.981	.014	.904	.037	.925	.038
45–54	.933	.030	.937	.030	.837	.056	.886	.059
55–64	.902	.045	.912	.046	.689	.094	.819	.112
65–74	.807	.060	.832	.061	.478	.116	.753	.183
75+	.616	.087	.674	.095	.285	.107	.917	.345
Gender								
Female	.948	.019	.955	.019	.860	.036	.927	.039
Male	.941	.010	.948	.010	.856	.018	.919	.019
Neurologic level								
T1-S5	.973	.009	.977	.009	.909	.020	.948	.021
C1-4	.868	.031	.879	.032	.744	.047	.842	.053
C5-8	.936	.015	.946	.015	.839	.028	.917	.031
Extent								
Incomplete	.955	.010	.964	.010	.870	.021	.951	.023
Complete	.924	.016	.929	.016	.836	.026	.878	.027

ratios for spinal unit remained nonsignificant, the ratios for cause became nonsignificant, and the ratio for gender became significant. Given the expectation that among SCI patients,[35,36] as in the general population, men have shorter survival times and that the influence of cause of injury on survival should be represented through neurologic level and extent of lesion, gender was included in and cause excluded from the final model. Spinal treatment unit was also excluded.

Assessment of the model residuals (eg, Martingale and partial residual plots) demonstrated the acceptability of the fit of the model to the data. Particularly, the log-cumulative hazard plot of the Cox-Snell residuals had zero intercept and unit slope ($t_{336}=-5.33$, $P<.05$). Although the gender difference was statistically significant, its magnitude was small compared with other variables in the model.

From the multivariate results (table 1), which control for other variables in the analysis, the following patterns were evident: (1) the hazard ratio increased significantly with age at injury over 45 years, when compared with subjects 15 to 24 year olds; (2) men had 1.4 times the risk of death that the women had; (3) low cervical tetraplegic subjects (C5-8) had 1.7 times the risk of death, and high cervical tetraplegics had 2.8 times the risk of death, when compared with paraplegic subjects; and (4) cases with complete lesions had 2.9 times the risk of death when compared with those with incomplete lesions.

Figures 2 through 5 present survival plots for each of the variables included in the multivariate model, illustrating the differences in survival for individual categories and demonstrating the appropriateness of the proportional hazards assumption underlying the Cox regression statistical procedure. Strong differences were demonstrated by age at injury group, neurologic level, and extent of lesion, and a weaker difference was found for gender.

Cumulative and Relative Survival Proportion: Univariate Results

Table 2 presents univariate results for 1- and 10-year cumulative and relative survival proportions for individual variables in the multivariate model. When compared with survival in the Australian population, it was found that, overall, SCI cases had 94.97% relative survival at 1 year and 92.09% relative survival at 10 years.

One-year cumulative survival proportion was 97.56% for subjects 15 to 24 years of age, declining to 61.60% in those aged 75 years and older. Relative survival was similar. Ten-year cumulative survival proportion in the most elderly group declined to 28.53%. Ten-year relative survival for this age at injury group (91.71%) had a wide CI (95% CI, ±34.50%), demonstrating high variability in survival and suggesting the need for caution in using the point estimate.

Survival and relative survival was poorer for men than women at 1 year and 10 years, but the differences were small.

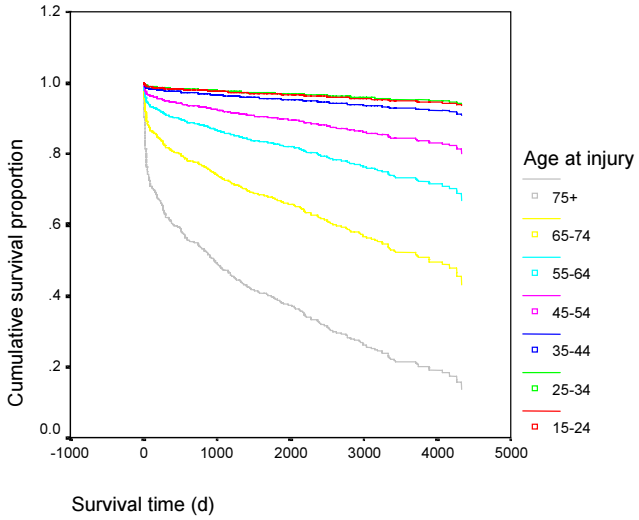

Fig 2. Survival plot for age at injury, plotted at the mean value of other variables in the model.

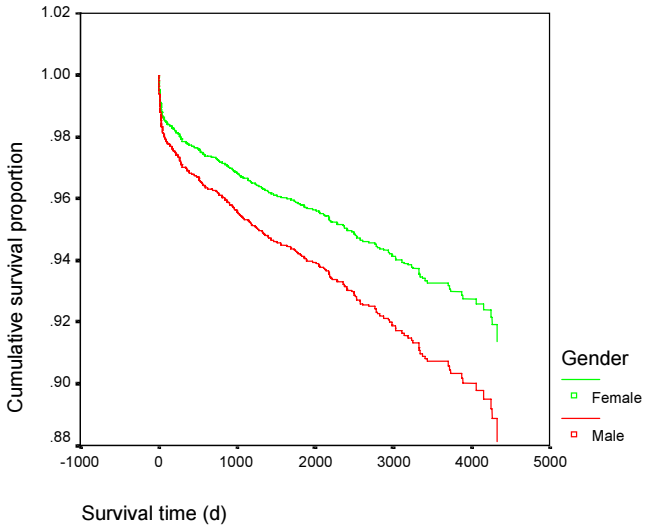

Fig 3. Survival plot for gender, plotted at the mean value of other variables in the model.

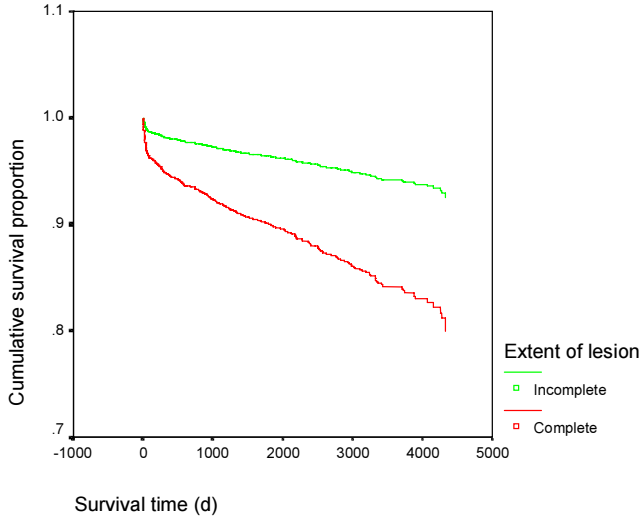

Fig 5. Survival plot for extent of lesion, plotted at the mean value of other variables in the model.

There were substantial differences in survival and relative survival by neurologic level and extent of lesion. The relative survival proportion of SCI cases with C1-4 level lesions was 84% of that of their peers in the Australian population. Among those with complete lesions, relative survival proportion was 88% of that of their peers.

Cumulative and Relative Survival Proportions: Stratified Results

Table 3 presents stratified 1-year cumulative and relative survival proportions. Gender was excluded because gender differences were small. In addition, some subgroups were combined because of small cell counts. When the number of deaths is less than 5, CIs based on the normal distribution can become asymmetric, leading to implausible values.[28] In this article, the protocol of the AIHW,[18] suppressing values based on death counts of less than 5, was followed. Stratified results for 10-year survival were not presented for the subgroups in table 3 because all death counts were less than 5 in each stratum. However, survival results beyond 1 year are presented in tables 4 and 5 for some subgroups for comparison with other studies, even though cell counts were small.

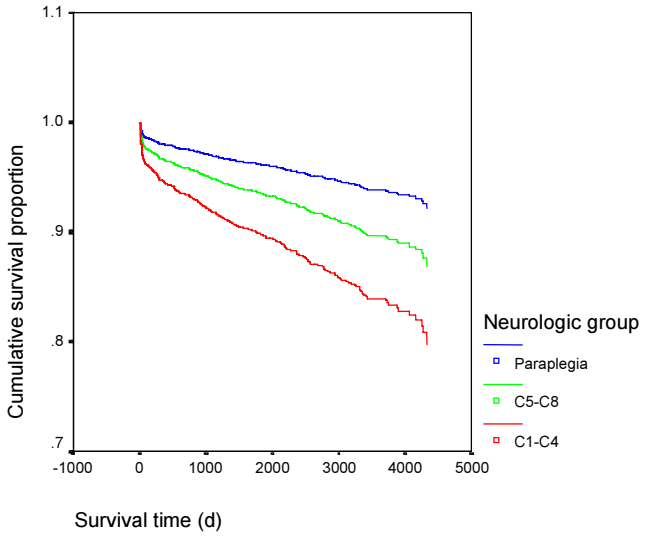

Fig 4. Survival plot for neurologic group, plotted at the mean value of other variables in the model.

Survival rates were much better for those with incomplete lesions and paraplegia, and in the groups injured at a younger age.

In those aged 15 to 34 years, 1-year relative survival proportion increased from 89.90% (95% CI, ±6.06%) in subjects with complete C1-4 tetraplegia to 98.73% (95% CI, 0.76%) in those with paraplegia. With increasing age, a substantial decline in 1-year relative survival proportion was notable in the most severely injured category (C1-4 complete tetraplegia) compared with other categories.

The poor survival and relative survival rates of elderly people with complete tetraplegia was notable. All subjects aged 75 years and over when injured and who had complete C1-4 tetraplegia died within the first year. Among those in the same age at injury group with complete C5-8 tetraplegia, only 8.33% survived the first year (relative survival proportion, 9.23%). Strong variability in survival was evident for some subgroups, as indicated by the size of the 95% CIs.

Periodic Changes in Survival

An assessment was made of changes in survival over time by splitting the case series into 2 incidence periods: incidents between 1986 and 1991 and incidents between 1992 and 1997. Two-month and 1-year survival was assessed. Cox regression modeling revealed a statistically significant reduction in the 2-month and 1-year hazard ratio from the earlier to later period when controlling for age at injury, gender, neurologic level, and extent of lesion (hazard ratio$_{2mo}$=.64; 95% CI, .43–.93; P=.01; hazard ratio$_{1y}$=.73; 95% CI, .54–.99; P=.04). From the earlier to later period, there was a 36% reduction in the risk of death at 2 months and a 27% reduction in risk at 1 year. There was an approximate 1-percentage point improvement in the cumulative survival proportion at each interval, between the 2 periods.

Exploratory analysis of the 2-month and 1-year period changes (1986–1991 vs 1992–1997) was undertaken using the

Table 3: One-Year Cumulative Survival Proportion and Relative Survival Proportion, Stratified Results

Age at Injury (y)	Neurologic Level	Extent	Cumulative Survival Proportion		Relative Survival Proportion	
			CSP	±95% CI	RSP	±95% CI
15–34	C1-4	Complete	.899	.061	.900	.061
15–34	C1-4	Incomplete	.952	.038	.953	.038
15–34	C5-8	Complete	.972	.021	.974	.021
15–34	C5-8	Incomplete	.986	.012	.987	.013
15–34	T1-S5	Complete or incomplete	.987	.008	.988	.008
35–64	C1-4	Complete	.717	.133	.720	.133
35–64	C1-4	Incomplete	.938	.046	.942	.046
35–64	C5-8	Complete or incomplete	.959	.023	.963	.023
35–64	T1-S5	Complete or incomplete	.971	.061	.975	.016
65–74	C1-4	Complete	.462	.277	.478	.286
65–74	C1-4	Incomplete	.846	.116	.872	.119
65–74	C5-8	Complete	.647	.232	.669	.240
65–74	C5-8	Incomplete	.855	.090	.880	.092
65–74	T1-S5	Complete or incomplete	.867	.101	.892	.104
75+	C1-4	Complete	NS	—	—	—
75+	C1-4	Incomplete	.697	.160	.767	.176
75+	C5-8	Complete	.083	NR	.092	NR
75+	C5-8	Incomplete	.667	.132	.734	.145
75+	T1-S5	Complete or incomplete	.731	.174	.775	.185

Abbreviations: NR, not reported (only 1 case survived beyond the first year); NS, none survived the first year.

log-rank test to compare survival functions within subgroups of cases defined by age at injury, sex, neurologic level, and extent of lesion. The analysis revealed a statistically significant improvement in 2-month survival for people aged 15 to 34 years and also for those aged 65 to 74 years (log $rank_{15–24yo}$=6.42, P=.01; log $rank_{25–34yo}$=4.24, P=.04; log $rank_{65–74yo}$=5.60, P=.02). For the younger age at injury group, there was an approximate 2-percentage point improvement in the 2-month cumulative survival proportion between the 2 periods. For the older group, there was a more than a 10-percentage point improvement. At 1 year, only the difference for 15 to 24 year olds was statistically significant, with an approximate 3-percentage point cumulative survival proportion difference (log $rank_{15–24yo}$=8.60, P<.01). No other subgroup differences were statistically significant at either 2 months or 1 year.

International Comparisons

The results of the most often cited studies of survival after SCI, focusing on survival from the date of injury or 1 day after injury, are summarized in tables 4 and 5. These include the results of a comparative analysis by Hartkopp et al[11] and comparative results from this study. Some other important studies[4,36] were excluded from the tables because they used different methods and/or did not report comparable cumulative and relative survival proportion results; they are, however, referred to in the Discussion section. Unfortunately, in none of the studies in the tables was the case series selected from a incidence period compable with that of our study, which was more recent.

Survival experience was similar in the United States, Denmark, and Australia. If CIs were not reported, it was not possible to know whether some differences were statistically significant; others were, as indicated by nonoverlapping 95% CIs. These could be chance findings, given the number of multiple comparisons undertaken.

DISCUSSION

Improvement in Survival

In Australia, 1-year survival from SCI is now approximately 95% of that of the general population for age and gender, and 92% at 10 years. Survival is even better in the young, in women, and in people with paraplegia and incomplete lesions. For example, a person suffering incomplete paraplegia, who is between ages 15 to 34 years, can now expect to achieve 1-year survival approximating 99% of that of other Australians in that age group. This development is encouraging and is in contrast to the experience in earlier decades. Sneddon and Bedbrook,[5] reporting on survival in Western Australia before 1979, found 87% 1-year survival for those with cervical lesions (C1-8). This is similar to the survival rate now experienced by C1-4 level tetraplegic subjects, and is substantially below that experienced by subjects with C5-8 tetraplegia (94%, table 3).

When survival through the first 18 months was excluded from analysis, our study showed that the 10-year cumulative survival proportion was approximately 93% for paraplegics patients and 87% for tetraplegic subjects. These results are similar to the 10-year results reported by Yeo et al[4] at year 10 of their 25-year survival study. Although this confirmatory evidence increases the confidence in their estimates of longer-term (25-y) survival in Australia, future monitoring is required because there have been, and may continue to be, changes in survival rates. It was apparent that Yeo[4] did not identify all deaths among the study cases, as discussed in the Methods section.

Improvements in survival were detected over 2 recent periods in Australia. The risk of death between 1992 and 1997 was significantly lower than that between 1986 and 1991, at 2 months and 1 year after injury. The greatest risk reduction (36% decline) occurred in the first 2 months. There was a consistent 1-percentage point increase in 2-month and 1-year cumulative survival proportion. These changes suggest both

Table 4: Comparison With Results of Other Studies, Cumulative Survival Proportion*

Study	Injury Period (end of follow-up)	Geographic Location	Selection Criteria	Cases (deaths)	Survival Parameter	Reference Study CSP (period)‡	Comparative Results Presented by Hartkopp et al[11] CSP (period)	Present Study† CSP (period)‡
Kraus et al[6]	Jan 1, 1971 to Dec 31, 1971 (Dec 31, 1976)	California	SCI cases residing in northern California that survived >1d	619 (320)	5–6y CSP	84% (1971)	91%–92% (1953–1990)	89%–90%±1% (1986–1997)
DeVivo et al[7]	Jan 1, 1973 to Dec 21, 1980 (Dec 21, 1981)	Multistate and multicenter, USA	SCI cases treated in 7 rehabilitation hospitals. Admitted within 1 y of injury and survived >1d. Losses to follow-up.	5131 (459)	7-y CSP	87% overall (1973–1980)	91% (1972–1990)	88%±1% (1986–1997)
						Incomplete paraplegia		
						95%±4% (1–24y)		
						90%±5% (25–49y)		98%±2%
						66%±14% (50+y)		78%±9%
						Complete paraplegia		
						95%±2% (1–24y)		
						90%±4% (25–49y)		93%±3%
						73%±10% (50+y)		67%±13%
						Incomplete tetraplegia		
						96%±2% (1–24y)		
						88%±5% (25–49y)		94%±3%
						56%±11% (50+y)		68%±6%
						Complete tetraplegia		
						89%±3% (1–24y)		
						80%±5% (25–49y)		88%±5%
						23%±12% (50+y)		41%±12%
DeVivo et al[8]	Jan 1, 1973 to Dec 31, 1984 (Dec 31, 1985)	Multistate and multicenter, USA	SCI cases treated in 13 rehabilitation hospitals. Admitted within 1y of injury and survived >1d. Losses to follow-up.	9135 (854)	7-y CSP	89% overall (1973–1984)	91% (1972–1990)	88%±1% (1986–1997)
					12-y CSP	85% overall (1973–1984)	83% (1972–1990)	83%±2% (1986–1997)
						Incomplete paraplegia		
						95%±3% (1–24y)		
						92%±3% (25–49y)		96%±3%
						73%±10% (50+y)		69%±15%
						Complete paraplegia		
						94%±3% (1–24y)		
						89%±3% (25–49y)		91%±4%
						61%±15% (50+y)		55%±17%
						Incomplete tetraplegia		
						95%±2% (1–24y)		
						89%±3% (25–49y)		90%±4%
						53%±13% (50+y)		46%±12%
						Complete tetraplegia		
						87%±3% (1–24y)		
						72%±6% (25–49y)		84%±7%
						18%±8% (50+y)		29%±15%
DeVivo et al[10]	Jan 1, 1971 to Dec 21, 1986 (NA)	Multistate and multicenter, USA	SCI cases treated in 6 rehabilitation hospitals. Admitted within 1y of injury and survived >1d. Losses to follow-up.	6563 (330)	2-y CSP‖	90%–94% (1973–1986)	97% (1972–1990)	93%±1% (1986–1997)
Hartkopp et al[11]	Jan 1, 1953 to Dec 31, 1990 (Dec 31, 1992)	Denmark	All SCI cases treated in rehabilitation hospital covering east and southeast Denmark, Greenland, and Faroe Island. Excludes patients requiring permanent respiratory support.	888 (236)	10-y CSP	86.8% (men, 1972–1990) 86.9% (women, 1972–1990)		85.6%±1.8% (men, 1986–1997) 86.0%±3.6% (women, 1986–1997)

Abbreviation: NA, not applicable.

*Studies that excluded day 1 deaths were included here because analysis of data from the present study showed that this had little effect on CSP and RSP. However, studies that excluded deaths in the first 3, 6, 12, or 18 months were excluded here because exclusion of these cases had an important effect on CSP and RSP.

†Comparative results from this study use the criteria underlined in the Selection Criteria column.

‡95% CI shown.

‖Based on 1898 cases admitted within 24 hours.

Table 5: Comparison With Results of Other Studies, Relative Survival Proportion

Study	Survival Parameter	Group (y)	Reference Study*	Present Study
DeVivo et al[7]	7-y RSP	Incomplete paraplegia		
		25–49	91%±5%	99%±2%†
		50+	76%±16%	91%±11%
		Complete paraplegia		
		25–49	92%±4%	95%±3%
		50+	83%±12%	81%±16%
		Incomplete tetraplegia		
		25–49	90%±6%	95%±3%
		50+	66%±13%	88%±7%†
		Complete tetraplegia		
		25–49	81%±5%	89%±5%
		50+	27%±14%	52%±15%
DeVivo et al[8]	12-y RSP	Incomplete paraplegia		
		25–49	95%±3%	99%±3%
		50+	97%±13%	91%±20%
		Complete paraplegia		
		25–49	92%±3%	93%±4%
		50+	82%±20%	82%±25%
		Incomplete tetraplegia		
		25–49	93%±4%	93%±4%
		50+	78%±19%	77%±20%
		Complete tetraplegia		
		25–49	74%±6%	86%±8%
		50+	27%±12%	46%±24%
Hartkopp et al[11]	10-y RSP	Men, 1972–90	93.8%	92%±2%
		Women, 1972–90	92.0%	93%±4%

*95% CIs were calculated by the author on the basis of information included in the reference study. The following formula was used to calculate the standard error (SE):

SE(RSP)=(SE[CSP])/(ESP)

where RSP is the relative survival proportion, CSP is the cumulative survival proportion, and ESP is the expected survival proportion.
†Statistically significant at .05 level.

improved acute hospital treatment and rehabilitation, as well as improved health maintenance after discharge.

Improvement in 2-month and 1-year survival between 1986 and 1991 compared with 1992 and 1997 was noted among people aged 15 to 24 years, for whom a 2- to 3-percentage point increase in cumulative survival proportion was observed. Improvement in 2-month survival was also noted for 25 to 34 year olds and 65 to 74 year olds. None of the other subgroup changes were statistically significant. Further research is required to determine the reasons for these relative differences. Findings such as these have not been reported elsewhere and it remains to be seen whether there is a conceivable clinical explanation or whether they represent a statistical anomaly.

Australians are not alone in experiencing improvements in survival rates. Indeed, based on the detailed comparative analysis presented here, there are strong similarities in the recent survival rates in Australia, Denmark, and the United States (tables 4, 5). This suggests that there may be a common experience and level of advancement in the care of SCI patients in those countries. Unfortunately, studies in other countries have not used comparable methods and have not reported results in a comparable format. This prevents a more comprehensive appraisal. An important gap is the lack of comparative information from developing countries. It is not known whether the experience in developed countries is being effectively translated to the developing world. This question needs more attention. An international comparative study is recommended, under the auspices of a relevant international body (eg, the World Health Organization), that would involve the professional expertise from the SCI research centers in the United States, England, Denmark, Australia, and other places.

A significant difficulty in comparing results of SCI survival studies arises as a consequence of methodologic differences such as different injury and follow-up periods; lack of uniformity in the time interval that constitutes the acute phase after injury (1d, 2wk, 3mo, 1y, 18mo); different case selection criteria and survival periods; losses to follow-up; small case series; different survival parameters reported; failure to report relative survival; failure to report CIs; and failure to stratify the results by important prognostic factors such as age at injury, neurologic level, and extent of lesion. One possible reason for the slightly better overall survival rates found in the present study compared with previous studies is the lower proportion of high-level neurologically complete tetraplegic subjects in this study.

Notwithstanding the methodologic differences, improvements in survival over time have been reported in several countries. In the United States, the all-cases 2-year survival rate increased from 90% between 1973 and 1977 to 94% between 1984 and 1986; the 7-year survival rate increased from 87% between 1973 and 1980 to 89% between 1973 and 1984.[7,8] Also in the United States, substantial improvements have been found in the most severely injured group. There was a 60% reduction in the mortality rate of ventilator-dependent people since 1980, compared with 1973 to 1979.[43] In Denmark, Hartkopp et al[11] found a 10% increase in the 10-year survival probability for men and a 21% increase for women between 1953 and 1971 and 1972 and 1990. In Canada, McColl et al[39]

found an increase in total life expectancy of nearly 5 years over that found by Geisler et al[44] a decade earlier for the same cohort. A similar improvement was found in England from the 1940s to the 1960s.[41] The comprehensive management of SCI in specialized facilities is commonly attributed as an important reason for improved early survival in many countries.[10,41,45] In addition, over time there have been substantial improvements in the methods of prevention and management of complications.[43]

Against the backdrop of these positive findings comes a note of caution. A recent appraisal of survival in the United States found continued improvement in 1-year survival from 1973 to 1977 to 1993 to 1998, but no improvement in survival beyond 1 year for the most recent period.[35] The study signals a warning that changes in health policies and reimbursement practices might degrade longer-term survival.[35] In Australia, it is most common for those who receive compensation for injury to receive a lump sum payout. However, anecdotally, it is reported that poor handling of funds is common among the injured. This would affect their capacity to maintain their own health and welfare, which could in turn affect their survival. The debate about the relative benefits and costs of lump sum payouts, structured settlements, and managed care needs to be very carefully considered. Unfortunately, a significant limitation of the quality of the debate is the lack of comparative information about the range of effects of such schemes on the health, welfare, and survival of those affected.

Further Improvement

Assessment of the means to improve survival from SCI further is facilitated by an understanding of the predictors, temporal patterns and causes of death, and by benchmarking.

Predictors of survival. Consistently, there have been several factors shown to be predictors of mortality for the SCI population. Age at injury and year of injury are 2 such factors. People injured at younger ages and those injured more recently have better survival outcomes.[3,35,39-42] Neurologic level and extent of lesion are also important predictors of mortality.[35,39-42] Some studies have also found gender[35,36] and life adjustment to be predictors.[46,47] The compounding effects of age, neurologic level, and extent of lesion have been shown by Alander et al.[37,38] They found a 60% mortality rate within the first 4 months among those aged 50 or more years with complete cervical cord injury.[38] The intermediate-term outcome for this group was also poor, with only 13% surviving the first year.[37] Subjects with incomplete injuries had a better outcome in the intermediate term, with 93% surviving the first year, but only 50% surviving to 5.5 years.[37]

In this study, age at injury, gender, neurologic level, and extent of lesion were all important predictors of survival with age at injury being the strongest. The age differential for SCI may not seem important, but, its importance is shown most readily in comparisons of relative survival (eg, for elderly SCI cases when compared with other elderly). Table 2 shows that for people with SCI who are 75 years or older at the time of injury, 1-year survival was only 67% of expectation. The stratified 1-year results for this age-at-injury group, presented in table 3, illustrate the compounding effects of age, neurologic level, and extent of lesion. Of those subjects with C1-4 complete lesions, none survived 1 year. Furthermore, people with C5-8 complete lesions had only 9% of 1-year survival expectation.

At any age, people with complete C1-4 level lesions have poorest relative survival at 1 year. Referring to table 3, a 90% relative survival was found for 15 to 34 year olds, declining to 72% in 35 to 64 year olds, further declining to 48% in 65 to 74 year olds and to 0% in those aged 75 years and older.

Temporal patterns of death. In Australia, half of the SCI deaths occurred in the first year after injury, with nearly two thirds of these deaths occurring within the first 2 months. The survival curve presented in the Results section (fig 1) demonstrates the importance of early deaths to the overall survival rates. It is also noteworthy that the greatest risk reduction between 1986 and 1991, compared with 1992 and 1997 (36% decline), occurred in the first 2 months after SCI, and yet the specific causes of this decline are unknown. Age-specific factors may be involved, in addition to general improvements in medical retrieval, assessment, and treatment. This requires further assessment.

Research focused on the distinct causes of death in the early posttraumatic period may provide a guide to treatment priorities. For example, Kraus et al[6] reported that cardiorespiratory complications (including pulmonary infarction, embolism, infection) accounted for 42% of deaths in the first 6 to 7 weeks. Alander et al[38] found that respiratory failure and pulmonary embolus were the main causes of death in the first 4 months among tetraplegic patients more than 50 years old. Harrop et al[48] examined the causes of early neurologic deterioration in patients with complete SCI. Harrop suggested that management of complete SCI can be improved through recognition of temporal patterns in the causes of neurologic deterioration and through earlier intervention. They found that early deterioration ($<$24h) was typically related to traction and immobilization, and that delayed deterioration (between 24th and 7d) was related to sustained hypotension in patients with fracture dislocations.

Other research has focused on minimization of posttraumatic tissue damage due to secondary reactive processes.[49] However, there is considerable controversy, and relatively little empirical data, about the efficacy of some of the recommended early treatments for these problems.[50-55]

Given the importance of early deaths in the overall survival rates from SCI, more attention to the causes and prevention of these deaths is recommended.

Cause of death. Changes in medical practice from the early 1970s have brought about a significant change in the causes of death. Prior to that time, renal failure was the primary cause.[56-58] Substantial decreases in respiratory and renal diseases have occurred since that time.[6,44,59] Whiteneck et al[41] observed that although genitourinary disorders accounted for 43% of deaths in the 1940s and 1950s, they accounted for only 10% in the 1980s and 1990s. Geisler et al[44] speculated that advances in the fields of antibiotics, renal dialysis, and medical and surgical expertise contributed to the decline in those disorders.

As the survival rate of the SCI population approaches that of the general population, the causes of death also appear to be approaching those of the general population.[3,41] However, many of the cause-specific death rates for SCI remain substantially above the general population, particularly for infections, primarily septicemia, and pneumonia,[3,11,60,61] but also for pulmonary emboli and suicide.[11,60,62,63] Improved methods of prevention and management of these conditions is required.

Studies of the causes of death, such as those discussed above, have generally focused on the direct causes. This was not possible in the present study because, until recently, the data have focused on the underlying cause of death, which gives more prominence to the external cause of the injury-producing event than to the direct causes of death. There is a need for a national study in Australia that would focus on these direct causes.

Benchmarking. For only the second time in the international literature,[36] survival rates have been reported for individual SCI treatment units to facilitate benchmarking. Although this is potentially controversial, the results are presented to illustrate that such comparisons can be made and the results are reported in a way that protects the identity of the individual units. There was no statistically significant difference in survival among patients from the 6 Australian spinal units. This demonstrates the comparability and efficacy of their services, and of the states' health and welfare services more generally. International benchmarking would be useful for determining and translating best practice, but only if methods can be fully standardized. Within Australia, the methods are standardized across spinal units, with central reporting to the ASCIR.[12] Partial standardization exists among selected facilities in parts of the United States.[64] However, there are differences between the Australian and US data systems, and these should be reconciled. In particular, there is a need for a common definition and prospective monitoring of ventilator-dependent tetraplegic patients and their survival, because they are a very high cost subgroup of cases.

CONCLUSIONS

Despite improvements, the survival rates of SCI patients remain a cause for concern. Survival of the elderly SCI population, and those with complete tetraplegia, is substantially below expectation, compared with the non-SCI population. Further improvement in survival rates can be achieved through a better understanding of the predictors, temporal patterns and causes of death, and by benchmarking. Early deaths have an important effect on overall survival rates, and should be the subject of more attention. International standardization of methods is strongly recommended so that comparative studies of survival can be undertaken.

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References

1. Australian Bureau of Statistics. Population by age and sex, Australian states and territories, June 1997 to June 2002. Canberra: ABS; 2003. Cat. No. 3201.0.
2. Australian Institute of Health and Welfare. National deaths index—description. Canberra: AIHW; 1997.
3. Samsa G, Patrick CH, Feussner JR. Long-term survival of veterans with traumatic spinal cord injury. Arch Neurol 1993;50:909-14.
4. Yeo JD, Walsh J, Rutkowski S, Soden R, Craven M, Middleton J. Mortality following spinal cord injury. Spinal Cord 1998;36:329-36.
5. Sneddon DG, Bedbrook G. Survival following traumatic tetraplegia. Paraplegia 1982;20:201-7.
6. Kraus JF, Franti CE, Borhani NO, Riggins RS. Survival with an acute spinal-cord injury. J Chronic Dis 1979;32:269-83.
7. DeVivo MJ, Kartus PL, Stover SL, Rutt RD, Fine PR. Seven-year survival following spinal cord injury. Arch Neurol 1987;44:872-5.
8. DeVivo MJ, Stover SL, Black KJ. Prognostic factors for 12-year survival after spinal cord injury. Arch Phys Med Rehabil 1992; 72:156-62.
9. DeVivo MJ, Stover SL. Long-term survival and causes of death. In: Stover SL, DeLisa JA, Whiteneck GG, editors. Spinal cord injury: clinical outcomes from the model systems. Gaithersburg: Aspen; 1995. p 289-316.
10. DeVivo MJ, Rutt RD, Black KJ, Go BK, Stover SL. Trends in spinal cord injury demographics and treatment outcomes between 1973 and 1986 [published erratum in: Arch Phys Med Rehabil 1992;73:1146]. Arch Phys Med Rehabil 1992;73:424-30.
11. Hartkopp A, Bronnum-Hansen H, Seidenschnur AM, Biering-Sorensen F. Survival and cause of death after traumatic spinal cord injury: a long-term epidemiological survey from Denmark [published erratum in: Spinal Cord 1997;35:862-4]. Spinal Cord 1997;35:76-85.
12. O'Connor PJ. Development and utilisation of the Australian Spinal Cord Injury Register. Spinal Cord 2000;38:597-603.
13. Thurman DJ, Sniezek JE, Johnson D, Greenspan A, Smith SM. Guidelines for surveillance of central nervous system injury. Atlanta: Centers for Disease Control and Prevention; 1995.
14. Maynard FM Jr, Bracken MB, Creasey G, et al. International Standards for Neurological and Functional Classification of Spinal Cord Injury. American Spinal Injury Association. Spinal Cord 1997;35:266-74.
15. Marino RJ, Barros T, Biering-Sorensen F, et al. International Standards for Neurological Classification of Spinal Cord Injury. J Spinal Cord Med 2003;26:S50-6.
16. O'Connor PJ. Epidemiology of spinal cord injury as determined by national population-based register [dissertation]. Adelaide (S Aust): Flinders Univ; 2003.
17. Kirshblum SC, Memmo P, Kim N, Campagnolo D, Millis S. Comparison of the revised 2000 American Spinal Injury Association classification standards with the 1996 guidelines. Am J Phys Med Rehabil 2002;81:502-5.
18. Australian Institute of Health and Welfare. Cancer survival in Australia, 2001. Canberra: AIHW; 2001.
19. Australian Institute of Health and Welfare. Breast cancer survival in Australian women 1982–1994. Canberra: AIHW; 1998.
20. National Occupation Health and Safety Commission. Work-related fatalities in Australia, 1989–1992. Sydney: NOHSC; 1998.
21. Australian Institute of Health and Welfare. Morbidity of Vietnam veterans: a study of the health of Australia's Vietnam veteran community. Volume 3: Validation study. Canberra: AIHW; 1999.
22. Jaro MA. Advances in record linkage methodology as applied to matching the 1985 census of Tampa, Florida. J Am Stat Assoc 1989;84:414-20.
23. Jaro MA. Probabilistic linkage of large public health data files. Stat Med 1995;14:491-8.
24. Felligi IP, Sunter AB. A theory of record linkage. J Am Stat Assoc 1969;64:1183-210.
25. Newcombe HB. Handbook of record linkage: methods for health and statistical studies, administration, and business. Oxford: Oxford Univ Pr; 1988.
26. Belsley DA, Kuh E, Welsch RE. Regression diagnostics: identifying influential data and sources of collinearity. New York: John Wiley & Sons; 1980.
27. Voutilainen ET, Dickman PW, Hakulinen T. Surv2: relative survival analysis program. Helsinki: Finnish Cancer Registry; 2000.
28. Hakulinen T, Gibberd R, Abeywickrama KH, Soderman B. A computer program package for cancer survival studies. Cancer Society of Finland. Helsinki: Finnish Cancer Registry; 1988. Publication No. 39.
29. Hakulinen T, Abeywickrama KH. A computer program package for relative survival analysis. Comput Programs Biomed 1985;19: 197-207.
30. Institute for Scientific Information. Science citation index. Philadelphia: ISI; 2001.
31. Institute for Scientific Information. Social science citation index. Philadelphia: ISI; 2001.
32. Ederer F, Axtell LM, Cutler SJ. The relative survival rate: a statistical methodology. Natl Cancer Inst Monogr 1961;6:101-21.
33. Esteve J, Benhamou E, Raymond L. Statistical methods in cancer research. Vol IV. Lyon: International Agency for Research on Cancer (WHO); 1994.
34. Collett D. Modelling survival data in medical research. London: Chapman Hall; 1994.
35. DeVivo MJ, Krause JS, Lammertse DP. Recent trends in mortality and causes of death among persons with spinal cord injury. Arch Phys Med Rehabil 1999;80:1411-9.

36. Frankel HL, Coll JR, Charlifue SW, et al. Long-term survival in spinal cord injury: a fifty year investigation. Spinal Cord 1998; 36:266-74.
37. Alander DH, Parker J, Stauffer ES. Intermediate-term outcome in cervical spinal cord-injured patients older than 50 years of age. Spine 1997;22:1189-92.
38. Alander DH, Andreychik DA, Stauffer ES. Early outcome in cervical spinal cord injured patients older than 50 years of age. Spine 1994;19:2299-301.
39. McColl MA, Walker J, Stirling P, Wilkins R, Corey P. Expectations of life and health among spinal cord injured adults. Spinal Cord 1997;35:818-28.
40. Kiwerski J. Factors contributing to the increased threat to life following spinal cord injury. Paraplegia 1993;31:793-9.
41. Whiteneck GG, Charlifue MA, Frankel HL, et al. Mortality, morbidity, and psychosocial outcomes of persons spinal cord injured more than 20 years ago. Paraplegia 1992;30:617-30.
42. Hackler RH. A 25-year prospective mortality study in the spinal cord injured patient: comparison with the long-term living paraplegic. J Urol 1977;117:486-8.
43. DeVivo MJ, Ivie CS. Life expectancy of ventilator-dependent persons with spinal cord injuries. Chest 1995;108:226-32.
44. Geisler WO, Jousse AT, Wynne-Jones M, Breithaupt D. Survival in traumatic spinal cord injury. Paraplegia 1983;21:364-73.
45. Griffin MR, Optiz JL, Kurland LT, Ebersold MJ, O'Fallon WM. Traumatic spinal cord injury in Olmsted County, Minnesota: 1935–1981. Am J Epidemiol 1985;121:884-95.
46. Krause JS, Sternberg M, Lottes S, Maides J. Mortality after spinal cord injury: an 11-year prospective study. Arch Phys Med Rehabil 1997;78:815-21.
47. Krause JS, Kjorsvig JM. Mortality after spinal cord injury: a four-year prospective study. Arch Phys Med Rehabil 1992;73: 558-63.
48. Harrop JS, Sharan AD, Vaccaro AR, Przybylski GJ. The cause of neurologic deterioration after acute cervical spinal cord injury. Spine 2001;26:340-6.
49. Ramer MS, Harper GP, Bradbury EJ. Progress in spinal cord research—a refined strategy for the International Spinal Research Trust. Spinal Cord 2000;38:449-72.
50. Bracken MB. High dose methylprednisolone must be given for 24 or 48 hours after acute spinal cord injury. BMJ 2001;322:862-3.
51. Bracken MB, Aldrich EF, Herr DL, et al. Clinical measurement, statistical analysis, and risk-benefit: controversies from trials of spinal injury. J Trauma 2000;48:558-1.
52. Bracken MB, Shepard MJ, Holford TR, et al. Methylprednisolone or tirilazad mesylate administration after acute spinal cord injury: 1-year follow-up. Results of the Third National Acute Spinal Cord Injury randomized controlled trial. J Neurosurg 1998;89:699-706.
53. Bracken MB, Shepard MJ, Holford TR, et al. Administration of methylprednisolone for 24 or 48 hours or tirilazad mesylate for 48 hours in the treatment of acute spinal cord injury. Results of the Third National Acute Spinal Cord Injury Randomized Controlled Trial. National Acute Spinal Cord Injury Study. JAMA 1997;277: 1597-604.
54. Short DJ, El Masry WS, Jones PW. High dose methylprednisolone in the management of acute spinal cord injury—a systematic review from a clinical perspective. Spinal Cord 2000;38:273-86.
55. Nesathurai S. Steroids and spinal cord injury: revisiting the NASCIS 2 and NASCIS 3 trials [see comments]. J Trauma 1998;45: 1088-93.
56. Jousse AT, Wynne-Jones M, Breithaupt DJ. A follow-up study of life expectancy and mortality in transverse myelitis. Can Med Assoc J 1968;98:770-2.
57. Freed MM, Bakst HJ, Barrie D. Life expectancy, survival rates, and causes of death in civilian patients with spinal cord trauma. Arch Phys Med Rehabil 1966;47:457-63.
58. Breithaupt DJ, Jousse AT, Wynne-Jones M. Late causes of death and life expectancy in paraplegia. Can Med Assoc J 1961;85:73-7.
59. DeVivo MJ, Kartus PL, Stover SL, Rutt RD, Fine PR. Cause of death for patients with spinal cord injuries. Arch Intern Med 1989;149:1761-6.
60. Soden RJ, Walsh J, Middleton JW, Craven ML, Rutkowski SB, Yeo JD. Causes of death after spinal cord injury. Spinal Cord 2000;38:604-10.
61. DeVivo MJ, Black KJ, Stover SL. Causes of death during the first 12 years after spinal cord injury. Arch Phys Med Rehabil 1993; 74:248-54.
62. Charlifue SW, Gerhart KA. Behavioral and demographic predictors of suicide after traumatic spinal cord injury. Arch Phys Med Rehabil 1991;72:488-92.
63. DeVivo MJ, Black KJ, Richards JS, Stover SL. Suicide following spinal cord injury. Paraplegia 1991;29:620-7.
64. Stover SL, DeVivo MJ, Go B. History, implementation and current status of the national spinal cord injury database. Arch Phys Med Rehabil 1999;80:1365-71.

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a. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.