Spinal Cord (1998) 36, 329–336

http://www.stockton-press.co.uk/sc

Mortality following spinal cord injury

John D Yeo[1], John Walsh[1], Sue Rutkowski[1], Ros Soden[1], Mary Craven[1] and James Middleton[2]

[1]*Spinal Injuries Unit, Royal North Shore Hospital, Sydney;* [2]*Moorong Spinal Unit, Royal Rehabilitation Centre, Sydney, Australia*

This study analyzed the mortality in 1453 spinal cord injured patients admitted early after injury to a specialised Spinal Injuries Unit within a University teaching hospital over a 40-year period. The cohort comprised 55.3% patients with cervical lesions and 44.7% patients with thoracic/lumbar lesions. Those patients who died within 18 months of the spinal injury (132) were excluded from the final analysis. Standardised Mortality Ratios, survival rates and life expectancy ratios were calculated for specific ranges of current attained age and duration since injury with reference to level and degree of spinal cord injury. The projected mean life expectancy of spinal cord injured people compared to that of the whole population was then estimated to approach 70% of normal for individuals with complete tetraplegia and 84% of normal for complete paraplegia (Frankel grade A). Patients with an incomplete lesion and motor functional capabilities (Frankel grade D) are projected to have a life expectancy of at least 92% of the normal population.

Keywords: tetraplegia; paraplegia; standardised mortality ratio; survival rate; life expectancy; mortality

Introduction

The estimated prevalence of citizens living in Australia suffering from significant paralysis following spinal cord injury now approaches 10 000. The main causes of traumatic spinal cord injury in the State of New South Wales have been identified as motor vehicle accidents (55%), including motor car, motor cycle and pedestrian injuries, falls and crushes (25%), and recreational and sporting accidents (15%), which are similar to other studies.[1,2]

Since the Spinal Injuries Unit (SIU) at the Royal North Shore Hospital (RNSH) in Sydney first commenced in 1953, there has been generally reported world-wide improvement in the acute survival of these patients through improved first-aid, rapid transportation to a specialised unit, skilled medical, surgical, and nursing care, and rehabilitation. While some patients still succumb to the effects of multiple trauma, previously common complications such as trophic skin ulceration leading to cellulitis and septicaemia, respiratory tract infection associated with sputum retention and recurrent urinary tract infection are now generally avoided or are adequately managed in specialised units.[3–9]

In 1985, several of the authors analyzed mortality in a population of 1370 paraplegic and tetraplegic patients admitted to this Spinal Unit between 1953 and 1984, including 25% of patients with paralysis from non-traumatic origin. Excluding those patients who died within the first 2 years following paralysis, the rate of mortality in the third and fourth decades of life in the remaining patients was calculated to be 400–500% of the normal community for complete tetraplegia, 150% of normal for incomplete tetraplegia, 200% of normal for complete paraplegia and 120% of normal for incomplete paraplegia. This previous study population differed significantly from the current study which has included only traumatic lesions and excluded deaths and exposure occurring within 18 months of injury. No ventilated tetraplegic patients were included in the previous study, whereas 10 have been included in the current study.

Minaire *et al.*, 1983, in a 10 year survey of 848 patients, reported that in 75% of the deceased patients the survival time was less than one fifth of theoretical life expectancy.[10] However, 1 year post-injury the trend in the life expectancy was towards normal values observed in the French population. Geisler reported, also in 1983, on a study of 1510 patients treated between 1973 and 1980, and compared the expectation of life in years for patients with either tetraplegia and tetraparesis or paraplegia and paraparesis at ages 20, 30, 40 and 50 years.[11] An improvement in life expectancy between 1973 and 1980, was identified in all groups. More recently Whiteneck *et al.*, 1992, studied 834 individuals with long-term spinal cord injuries treated at the National Spinal Injuries Centre at Stoke Mandeville Hospital and The Regional Spinal Injuries Hospital at Southport.[8] There was a predominance of paraplegia or

Correspondence: JD Yeo, North Shore Medical Centre, 66 Pacific Hwy, St. Leonards 2065, Australia

paraparesis (60%) in the total group. The mean survival time of the total group was 32 years, with an increase from a median survival of 26 years in those patients admitted in the 1940s to 33 years in those admitted 20 years later. This reported improvement in mortality and life expectancy encouraged the authors to further review the mortality in patients treated in the SIU at RNSH.

Aims

(1) To analyze the mortality of individuals with traumatic spinal cord injury (SCI) admitted to the SIU at RNSH between January, 1955 and December 1994;
(2) To compare these results with other reported studies.

Methods

Data collection

A review of all patients who had sustained traumatic SCI between January, 1955 and the end of December, 1994 and admitted to the RNSH was undertaken. Details were obtained from a card reference data base in the SIU and from the Medical Records Department. Where there was no recent recorded clinical contact, researchers made three telephone calls to seek further information and, if unsuccessful, a letter was sent to the patient's last known address. Information on the total patient group was collated with the records obtained from the State Office registering Births, Deaths and Marriages of NSW citizens. The published electoral rolls for NSW and membership list of the Paraplegic and Quadriplegic Association of New South Wales were additional sources providing information for patient contact.

Excluded from the final data analysis were patients with spinal cord concussion or spinal injury with no permanent spinal cord damage. Also excluded were those patients where available information was inadequate for the necessary classification. The main characteristics of patients included in the analysis were as follows:

- unique identifier (name and unit record number)
- gender (however, because of the relatively small number of females, males and females were combined after the initial data analysis)
- date of birth
- date and cause of injury
- date of death (if applicable)
- severity of injury categorised as illustrated in Table 1. The majority of unclassified patients had died within 18 months of injury, and so were excluded from the main analysis of mortality.

Data analysis

The data was analyzed by the Consultant Actuary using the following procedures:

(a) In all cases, periods were measured exactly in days and all fractions of a year contributed to the totals.

(b) All deaths and exposure in the study group within 18 months of injury were tabulated to estimate the acute death rate, but were excluded from the longer term analysis in life expectancy.

(c) The acute mortality and long-term mortality groups were further sub-divided into 20 major groupings, being for patients with cervical and thoracic/lumbar lesions separately by:

   (i) Severity of lesion: All, Frankel A,B,C and D (10 groups);
   (ii) Year of injury: Up to and including 1980, and after 1980 (four groups);
   (iii) Age at injury: Less than 25 years, 25 to 39 years and 40 years and over (six groups).

(d) For each of these major groupings, the number of deaths (d_x) and the aggregate years of exposure (E_x) were tabulated across the period of investigation from date of injury until death, withdrawal alive from the analysis, or the end of December, 1994 where 'x' took the value of:

   (i) Current attained age in decimal groups from 20 to 80 years to measure age-specific mortality; or
   (ii) Duration after injury – for the first 18 months, 18 months to 3 years; 2 year period to 5 years, and then 5 year groupings to 30 years to measure duration-specific mortality.

The mortality rate for each particular group was then estimated as $q_x = d_x/E_x$, using the accepted methodology as described in Lilienfeld and Stolley (1994).[12] In the case of the duration-specific investigation a cumulative survival probability was estimated, using the life-table techniques as described in Cutler and Ederer (1958).[13]

(e) For each group a *Standardised Mortality Ratio (SMR)* was calculated, being the ratio of (Actual number of deaths observed): (Number of deaths expected using population mortality). 'Population mortality' was from the Australian Life Tables 1985–87 (ALT 85–87), using 80% male and 20% female mortality, in accordance with the approximate spread of year of death, exposure to the risk of death and gender distribution of the sample. The median year of exposure is more recent than one might expect from the wide spread of years of onset (1955 to 1995); this is explained by a rapid increase in the rate of incidence in the 1970s. A 95% confidence limit was calculated for the SMR of each group. In the case of the survival rate analysis, an expected survival rate was estimated by applying ALT 85–87 survival rates to the study sample.

(f) For the projected expectation of life at each attained age, the sequence of observed SMRs over the remaining lifetime was studied, and a curve assumed using the observed values and the surrounding confidence limits and a factor to allow for future improvement in mortality. This allowed the derivation of a smooth sequence of attained age-specific mortality rates appropriate to the population. In each case the complete expectation of life at attained age X was then calculated as the sum of cumulative survival probabilities for all future ages. This was then compared with the population expectation of life at each attained age to derive a percentage of population appropriate in each group.

Results

Summary of data

From a total of 1823 patients with traumatic SCI identified on the data base, 210 patients were excluded from this study because they had transferred interstate or overseas within 18 months of injury. A further 160 patients were excluded because there was inadequate clinical information. The remaining 1453 comprised 803 patients with cervical lesions and 650 patients with thoracic/lumbar lesions. Twenty-two patients included in the analysis and later lost to follow-up were withdrawn alive from the study at the date of last contact.

There were 82% males and 18% females in the study population. Those patients with cervical lesions comprised 55% of the sample.

Frankel classifications were obtained when possible with a total of 42 cervical lesions and 10 thoracic/lumbar lesions not classified: the majority of these had died within 18 months of injury, and so were excluded from the long-term analysis. A further 41 cervical lesions and 13 thoracic/lumbar lesions were Frankel E group on follow-up after discharge. In the combined cervical and thoracic/lumbar groups, patients with complete lesions (ie Frankel A) (54%) outnumbered incomplete lesions (ie Frankel B–D). Ten of the tetraplegics were ventilator dependent. Six of these had died (five within 18 months of injury and one subsequently).

For all casualties Transport injuries contributed the major number of injuries (54% overall), followed by Falls with 18% and Sport and Recreation with 18%. However, 29% of cervical lesions were sustained in sporting and recreational accidents, consisting of water sports, football and horseriding.

Year of injury

The sample was subdivided into year of injury (Table 2) up to calendar year 1980 and after 1980. Significant numbers of admissions did not begin to emerge until the 1970s and continued through that decade; admission numbers peaked in the mid-1980s, and have been declining since then. Overall, the sample comprised 649 admissions (45%) with an injury date on or before 31 December 1980, and 804 (55%) after that date. A smaller percentage of cervical lesions were contained in the earlier group, possibly reflecting the improved early intervention system which has been developed in recent years resulting in an increased percentage of surviving high level tetraplegic casualties.

Age at injury

The sample was also divided into three broad groups of Age at injury, less than 25 years, 25 to 39 years, and 40 years and over (Table 3). 45% of the total sample were in the youngest age group at injury.

Acute survival

Thirty-five patients with thoracic/lumbar injuries (5%) and 97 patients with cervical lesions (12%) died within 18 months of injury. A much higher death rate occurred in patients with complete high cervical lesions when compared with the death rate in patients with low cervical lesions in the 18 months after injury.

Table 1 Frankel classification (after discharge from hospital)

Frankel level	*Cervical lesions*	*Thoracic/ lumbar lesions*	*Combined*
A	337	391	728
B	105	37	142
C	69	38	107
D	209	161	370
E	41	13	54
Unclassified	42	10	52
Total	803	650	1453

Table 2 Year of injury

Year of injury	*Cervical lesions*	*Thoracic/ lumbar lesions*	*Combined*
Up to 31/12/1980	337	312	649
After 31/12/1980	466	338	804
Total	803	650	1453

Table 3 Age at injury

Age at injury	*Cervical lesions*	*Thoracic/ lumbar lesions*	*Combined*
Less than 25 years	344	307	651
25 to 39 years	209	200	409
40 years and over	250	143	393
Total	803	650	1453

The analysis by year of injury in 1453 patients studied showed similar rates of acute mortality for the group before 1981 when compared to the group in 1981 and later. For all patients, those aged 40+ years at injury had significantly higher rates of acute mortality than younger admissions; for example, of 250 patients with cervical lesions admitted aged 40+ years, 63 had died within 18 months (a rate of 25%).

Survival rates
Excluding those patients who died within 18 months of injury (132), the overall survival rate for the combined group of paraplegic and paraparetic individuals at 25 years' duration was 80% compared to an expectation on the ALT 85–87 of 88% – a ratio of 91%. For the combined group of tetraplegic and tetraparetic individuals at 25 years, the survival ratio was 72% compared to ALT 85–87 of 89% – a ratio of 81%.

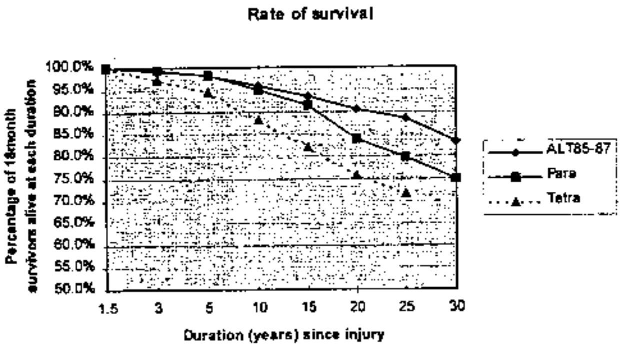

Figure 1 Rate of survival

The graph was not extended to 30 years for the latter group because of the sparsity of data at this duration after injury (Figure 1).

Age-specific mortality rates
The major analysis in this study was in deriving current attained age-specific standard mortality ratios (SMRs) for use in estimating the long-term extra mortality which might be expected in the population with a spinal cord injury (Table 4). Patients who died in the first 18 months after injury were excluded, as was all exposure for the first 18 months after injury. Patients in Frankel categories B and C were also excluded in the detailed presentation because of insufficient numbers for credible data analysis as separate groups.

The major findings identified in the analysis of mortality rates were (Table 5):

- A greater mortality among people who have sustained spinal cord injury – more pronounced among tetraplegics than paraplegics and among people with complete as opposed to incomplete lesions;
- A consistent trend of a reduction in SMR with advancing current attained age across all groups studied – this supports the practice of a reducing mortality loading with advancing attained age in projecting expectation of life;
- Considerable uncertainty in the actual SMR at any single attained age group (ie wide confidence limits), but with reasonable consistency between adjacent attained age groups (thereby reducing the coefficient of variation of the combined groups).

Table 4 Distribution of deaths

Frankel level	*Number of people in category*	*Number of deaths in 1st 18 months*	*Acute death rate (%)*	*Exposure (years) after 18 months*	*Number of deaths after 18 months*	*Crude long term death rate (%)*
Cervical						
C1–C4 A	102	22	21.6	859	14	1.6
C5–C8 A	235	23	9.8	2606	59	2.3
B	106	3	2.9	1280	10	0.8
C	69	9	13.0	556	10	1.8
D	209	7	3.3	1914	24	1.3
E	41	0	0.0	424	1	0.2
Unclassified	42	33	78.6	13	1	7.7
All	803	97	12.1	7652	119	1.6
Thoracic lumbar						
A	391	25	6.4	5051	59	1.2
B	37	0	0.0	498	1	0.2
C	38	1	2.6	390	3	0.8
D	161	4	2.5	1750	15	0.9
E	13	0	0.0	116	0	0.0
Unclassified	10	5	50.0	26	0	0.0
All	650	35	5.4	7831	78	1.0

- In the total group of patients with a cervical lesion, a SMR of around 520% at younger attained ages (less than 40 years) was estimated, reducing to 400% at attained ages 40 to 60 years, and 180% for those over the attained age of 60 years.
- In the total group of patients with a thoracic/lumbar lesion, a SMR of 320% at younger attained ages (less than 40 years) was estimated, reducing to 240% at attained ages of 40 to 60 years, and 150% over the age of 60 years.

Life expectancy
The observed SMRs were applied to the population mortality rates (ALT 85–87) to derive amended

Table 5 Standard mortality ratios

Category	*20–30 years*	*30–40 years*	*40–50 years*	*50–60 years*	*60–70 years*	*70–80 years*	*All ages*
Cervical lesions							
Combined group							
Central estimate	6.5	4.8	4.8	3.1	2.0	1.6	2.4
Upper 95% limit	8.5	7.5	7.0	4.4	2.8	2.3	2.8
Lower 95% limit	2.7	2.2	2.6	1.8	1.1	1.0	2.0
C1 to C4: Frankel A							
Central estimate	8.4	8.6	5.6	4.4	3.5	28.8	6.4
Upper 95% limit	17.8	18.2	13.4	9.3	10.2	n/a	9.7
Lower 95% limit	0.0	0.0	0.0	0.0	0.0	n/a	3.1
C5 to C8: Frankel A							
Central estimate	10.9	7.9	9.8	4.9	5.6	2.6	5.6
Upper 95% limit	17.9	13.3	14.7	8.3	8.6	4.9	7.0
Lower 95% limit	3.8	2.5	4.9	1.6	2.6	0.2	4.2
C1 to C4: Frankel D							
Central estimate	4.2	3.9	1.2	1.7	0.7	1.4	1.1
Upper 95% limit	9.9	9.4	3.6	3.3	1.5	2.3	1.6
Lower 95% limit	0.0	0.0	0.0	0.0	0.0	0.5	0.7
Thoracic/lumbar lesions							
Central estimate	3.1	3.4	3.1	1.8	1.4	1.6	1.9
Upper 95% limit	5.3	5.5	4.9	2.8	2.2	2.4	2.3
Lower 95% limit	1.0	1.3	1.4	0.8	0.7	0.8	1.5
Frankel A							
Central estimate	4.3	3.6	4.2	2.5	1.7	1.4	2.3
Upper 95% limit	7.5	6.2	6.7	4.0	2.7	2.3	2.8
Lower 95% limit	1.1	0.9	1.7	1.0	0.7	0.5	1.7
Frankel D							
Central estimate	0.0	5.0	1.3	1.0	1.1	1.9	1.4
Upper 95% limit	n/a	10.7	4.0	2.3	2.2	3.5	2.1
Lower 95% limit	n/a	0.0	0.0	0.0	0.0	0.3	0.7

Table 6 Expectation of life*

		Expectation of life in years and % of ALT 85–87					
		Cervical lesions			*Thoracic/lumbar lesions*		
Age (years)	*ALT 85–87 Years*	*All Years (%)*	*Frankel A Years (%)*	*Frankel D Years (%)*	*ALL Years (%)*	*Frankel A Years (%)*	*Frankel D Years (%)*
25	50.5	40.2 (79%)	34.9 (69%)	46.5 (92%)	43.7 (86%)	42.4 (84%)	46.5 (92%)
35	41.0	32.5 (79%)	27.8 (67%)	38.1 (92%)	35.5 (86%)	34.2 (83%)	38.1 (92%)
45	31.6	24.8 (78%)	20.9 (66%)	29.4 (92%)	27.2 (85%)	26.1 (82%)	29.4 (92%)
55	22.9	18.1 (79%)	15.3 (66%)	21.3 (92%)	19.8 (86%)	19.1 (83%)	21.3 (92%)
65	15.3	12.4 (80%)	10.6 (68%)	14.4 (93%)	13.7 (89%)	13.3 (86%)	14.4 (93%)

*In projecting the expectation of life of patients with Frankel D categorization, the authors found no significant statistical justification in adopting a different mortality assumption for paraplegics as opposed to tetraplegics mortality Tables appropriate to the major groups of thoracic/lumbar and cervical lesions, for (a) the whole, and (b) the four study sub-groups of patients with complete and incomplete lesions (Frankel D). The results are presented for decennial ages in Table 6. These life expectancies are presented in percentages, as well as in years to allow for consideration of improvement in population life expectancies over time.

The main features of this analysis were:

- An estimated mean life expectancy for the full sample of patients (Frankel A and Frankel D) with cervical lesions was 79%, and for patients with thoracic/lumbar lesions was 86% compared to that of the whole population.
- For complete lesions, mean life expectancy approached 70% for tetraplegics and 84% for paraplegics.
- For incomplete lesions (Frankel D), mean life expectancy was at least 92% for both tetraparetic and paraparetic casualties.

Discussion

This study on spinal cord injured patients admitted early to a specialised Spinal Unit within a University teaching hospital over a 40 year period confirmed an anticipated reduction in life expectancy, with increased mortality in this population known to result from complications such as pneumonia, septicaemia, cardiovascular disease and suicide.[14] In high level tetraplegic patients, there is potential for more serious respiratory complications with an increased risk of respiratory failure and progressive atelectasis associated with diaphragmatic fatigue, which may be accelerated by hypoxia and bradycardia.[15-17]

This study found that a higher mortality occurred in the first 18 months after injury. Important prognostic factors for survival found were level and degree of neurological impairment as well as age, confirming results in previous studies.[4,8,9] The importance of early admission to a specialised spinal unit has previously been emphasised by DeVivo *et al.*, 1990, in a retrospective review of 794 spinal cord injured patients admitted to the University of Alabama Hospital between 1973 and 1985.[18] They found statistically significant reductions in acute care requirements and total length of stay, coupled with a highly significant reduction in the incidence of pressure ulcers in those patients admitted within 24 h of injury. These findings confirmed a previous observation by the same author that enhanced acute survival rates occur in patients admitted without delay, justifying the establishment of specialised spinal cord injury systems to treat patients.

Prior to 1950 the life expectancy for spinal cord injured individuals was poor.[11] Burke *et al.*, 1960, published data from a series of 5575 patients. In the group under 35 years at the time of injury and who had survived the first year after injury, they identified that 80% were likely to be alive 10 years after injury.[19] In a more recent study by Whiteneck *et al.*, 1992, the mean survival time of the total group was 32 years.[8] While, Samsa *et al.*, 1993, reported that, in a study of over 5500 male veterans with traumatic spinal cord injury who survived at least 3 months after injury, there was a mean life expectancy of 85% compared to a similarly aged American male.[20] In a study by DeVivo *et al.*, 1993, of over 9000 patients injured between 1973 and 1984, surviving at least 24 h after injury and admitted within 1 year of injury to one of the 13 designated model US Regional Spinal Unit Care Systems in the USA, the overall 12 year cumulative survival in the series was 85.1%, increasing to 88.3% when only persons who survived the first post-injury year were considered.[21] On comparing these results with their previous report studying 7 year survival it was clear that mortality rates had declined.[7]

DeVivo and colleagues summarised some of the difficulties in interpreting many of the studies of survival after spinal cord injury which have been published over the last 20 years.[7,21] Inconsistencies had inevitably resulted from differences in study population characteristics, research designs and analytical methods. In some studies a large number of patients had been lost to follow-up or included where there had been an extended period between initial injury and entry into the study. Failure to control for factors of prognostic importance such as age at injury, level of lesion and degree of neurological impairment may also limit the value of a study.

Whilst previous studies of life expectancy after spinal cord injury had most commonly been divided into groups of complete and incomplete paraplegia or tetraplegia, DeVivo *et al.*, 1992, noted that survival rates amongst incomplete lesions varied considerably depending on degree of impairment. They reported survival rates in groups with sensory sparing only or non-functional motor strength (Frankel grades B and C) to be closer to the individuals with neurologically complete lesions (Frankel A) than to those with functional motor capability below the level of injury (Frankel D). In addition, they described differences in life expectancy within the tetraplegic group, depending on exact neurological level.[7] As a result, DeVivo *et al.*, 1995, suggested that a more effective way to group spinal cord injured individuals for survival analysis was the following: (i) injury level between C1-4 with Frankel grade A, B or C; (ii) injury level between C5-8 with Frankel grade A, B or C; (iii) thoracic, lumbar or sacral injury with Frankel grade A, B or C and (iv) Frankel grade D regardless of injury level.[14]

More recently Coll *et al.*, 1996, questioned the validity of grouping SCI individuals by combining varying degrees of neurologic completeness and level of lesion when considering survival outcomes.[22] They evaluated the homogeneity of various groups and found the previously described groupings of tetraplegia (Frankel A, B and C), paraplegia (Frankel A, B and C) and all Frankel D's combined, as well as clinical groupings of complete and incomplete tetraplegia/paraplegia, not appropriate for their study sample spanning 50 years from 1943–1993. These authors offered an alternative method of classifying cases for mortality risk and outcome, where categories included C1–4 Frankel A tetraplegia; C5–8 Frankel A tetraplegia; T1–L1 Frankel A paraplegia combined with C1–T6 Frankel B and C levels; and all individuals with Frankel D combined with T7–S5 Frankel B and C and L2–S5 Frankel A paraplegia. The authors, however, acknowledged that further validation was necessary.

In this study, the authors have calculated the range of life expectancy following SCI, particularly in the readily identifiable clinical categories Frankel A and D. These two groups comprise the majority of exposure in our study with more than 12 000 years of exposure between them compared to less than 3000 years of exposure for the Frankel B and C groups combined.

These statistics provide a framework within which life expectancy can be considered for each individual. However, care must be taken when applying projections for life expectancy for an individual from grouped data. In applying these estimates of life expectancy one must be careful not to discount expected improvements in survival of patients who have sustained spinal cord injury, compared to the general population. The most reliable estimate of this improvement in a large sample was provided by DeVivo and Stover,[14] where they observed a rate of improvement of 3.4% per annum over a 20 year period to 1993 in the standardised rate of mortality among people with spinal cord injury. In the general population, the Australian Institute of Health and Welfare[23] reported an annual rate of improvement in the standardised rate of Australian mortality of 1.8% per annum. This implied a net rate of improvement of 1.6% per annum in the population of people with spinal cord injury; allocation of this annual improvement to projections of life expectancy would yield, for example, results of 77% of the population life expectancy for those with complete tetraplegia (Frankel A), 91% for those with complete paraplegia (Frankel A) and 96% for the group classified as Frankel D. Factors such as neurological level and Frankel grade, ventilator status, ethnic background, race, psycho-social adjustment, presence of pre-existing or unrelated concurrent medical conditions, length of post-injury survival to date, motiviation in self-care and availability of medical and attendant care may influence projections.[14]

Conclusion

The study has confirmed our earlier impression that patients with spinal cord injury have reduced life expectancy, with both the level and severity of lesion being important determinants. The results of this study provide a rational basis upon which life expectancy can be considered for each individual patient suffering from spinal cord injury in the present and near future.

Acknowledgements

The authors gratefully acknowledge the Research Grants from the Motor Accidents Authority of NSW and the Spinal Injury Research Fund, Royal North Shore Hospital, which enabled the research and medical records staff to search for and record the data over a period of nearly 2 years. In particular we thank Ms Gudrun Hofmann, departmental secretary, for her most helpful assistance.

References

1 DeVivo MJ, Fine PR, Maetz H, Stover SL. Prevalence of spinal cord injury: A reestimation employing life table techniques. *Arch Neurol* 1980; **37**: 707–708.
2 Nakajima GG *et al*. The disease pattern and causes of death of spinal cord injured patients in Japan. *Paraplegia* 1989; **27**: 163–171.
3 Freed MM, Bakst HJ, Barrie DL. Life expectancy, survival rates, and causes of death in civilian patient with spinal cord trauma. *Arch Phy Med Rehab* 1966; **47**: 457–463.
4 Guttmann L. *Spinal cord injuries. Comprehensive management and research*. Blackwell Scientific Publications 1973, p631.
5 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**: 486–488.
6 DeVivo MJ, Kartus PL, Stover SL *et al*. Seven-year survival following spinal cord injury. *Arch Neurol* 1987; **44**: 872–874.
7 DeVivo MJ, Stover SL, Black KJ. Prognostic factors for 12-year survival after spinal cord injury. *Arch Phys Med Rehabil* 1992; **73**: 156–162.
8 Whiteneck GG, Charlifue SW, Frankel HL *et al*. Mortality, morbidity, and psychosocial outcomes of persons spinal cord injured more than 20 years ago. *Paraplegia* 1992; **30**: 617–630.
9 Tator CH *et al*. Neurological recovery, mortality and length of stay after acute spinal cord injury associated with changes in management. *Paraplegia* 1995; **33**: 254–262.
10 Minaire P, Demolin P, Bourret J *et al*. Life expectancy following spinal cord injury: A ten-years survey in the Rhone-Alpes region, France 1969–1980. *Paraplegia* 1983; **21**: 11–15.
11 Geisler WO, Jousse AT, Wynne-Jones M, Breithaupt D. Survival in traumatic spinal cord injury. *Paraplegia* 1983; **21**: 364–373.
12 Lilienfeld DE, Stolley PD. Foundations of Epidemiology. Oxford University Press, 1994.
13 Cutler SJ, Ederer F. Maximum utilisation of the life table method in analyzing survival. *J Chron Dis* 1958; **8**: 699–712.
14 DeVivo MJ, Stover SL. Long-term survival and causes of death; Chapter 14 in spinal cord injury: *In:* Stover SL, Delisa JA, Whiteneck GG. (eds). *Clinical outcomes from the model systems*. An Aspen Publication, Maryland, 1995.
15 Wicks AB, Menter RR. Long-term outlook in quadriplegic patients with initial ventilator dependency: *Chest* 1986; **90**: 406–410.
16 Carter RE. Respiratory management, including ventilator care in tetraplegia and diaphragmatic pacing. *Handbook of Clinical Neurology* 1992; **61**: Vol 17, Elseveir Science.
17 Carter RE. Experience with ventilator dependent patients. *Paraplegia* 1993; **31**: 150–153.
18 DeVivo MJ, Kartus PL, Stover SL, Fine PR. Benefits of early admission to an organised spinal cord injury care system. *Paraplegia* 1990; **28**: 545–555.

19 Burke ME, Hicks AF, Rollins M, Kessler H. Survival of patients with injuries to the spinal cord. *JAMA* 1960: **172:** 121–124.
20 Samsa GP, Patrick CH, Feusser JR. Long-term survival of veterans with traumatic spinal cord injury. *Arch Neurol* 1993; **50:** 909–914.
21 De Vivo MJ, Black KJ, Stover SL. Causes of death during the first 12 years after spinal cord injury. *Arch Phys Med Rehabil* 1993; **74:** 248–254.
22 Coll J *et al.* Evaluation of homogeneity in determining appropriate groupings for mortality risk in spinal cord injury. *Spinal Cord* 1997; **35:** in press.
23 Australian Institute of Health & Welfare. *Australia's Health 1996*. Table S15, p220. Australian Government Publishing Service. Canberra 1996. ISBN 0 642 24706 4.