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ORIGINAL ARTICLE

Survival after traumatic spinal cord injury in Denmark: a hospital-based study among patients injured in 1990–2012

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Study design: Hospital-based cohort study at Spinal Cord Injury Centre of Western Denmark (VCR).
Objective: To examine the overall survival and mortality over time adjusted for age at the time of injury and gender.
Methods: Review of medical records of traumatic spinal cord injury (TSCI) patients admitted at VCR between 1990 and 2012. The patients were followed up until death, emigration or end of study (December 2014). Survival and mortality rate ratios (MRRs) with 95% confidence intervals (CI) were estimated for sub-groups defined by year of injury (1990–1994, 1995–1999, 2000–2004, 2005–2009 and 2010–2012). Mortality was analysed using Cox proportional hazard regression. Adjustment for gender and age at injury was performed (restricted cubic splines).
Results: In total, 665 patients (males 82%) were followed; 136 (20%) patients died during the observation period. Two-year survival varied from 93% in 2005–2009 to 98% in 2000–2004. Using 1990–1994 as a reference, the adjusted MRRs varied between 1.22 (CI: 0.43; 3.42) and 0.48 (CI: 0.13; 2.71). The 5- and 10-year survival varied between 85% (2005–2009) and 95% (1990–1994), and between 77% (2005–2009) and 91% (1990–1994), respectively. No trend over time was observed either for 2-, 5- or 10-year survival. Men's mortality did not differ consistently from that of women. Except for the most recent time period, the overall survival after TSCI was higher among those aged <60 years at time of injury.
Conclusion: Survival after TSCI in Denmark did not change considerably from 1990 to 2014, and there seemed to be no gender difference. Mortality was highest among patients above 60 years of age at injury.
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INTRODUCTION

Overall, mortality following traumatic spinal cord injury (TSCI) has shown a decreasing trend over time.[1] Comparing the decade 1943–1952 with the reference decade 1981–1990, Frankel *et al.*[2] found that the mortality-rate-ratio (MRR) after adjustment for age, gender and injury level and completeness was 3.5 and 5.6, respectively, in two British centres. They explained the reduction in mortality by the introduction of modern emergency treatment enabling more individuals to be transferred to rehabilitation units. Subsequently, in Australia,[3] the period 1986–1991 was compared with 1992–1997 in a study that showed a reduction in mortality that was largest in the acute phase up to 2 months post injury, and this was explained by improved acute treatment and early post-injury treatment and rehabilitation. Similarly, in the US,[4] an improvement in the short-term survival (up to 2 years post injury) was found, but there was no substantial decline in mortality after the first 2 years post injury. Recently, Shavelle *et al.*[5] investigated long-term survival among more than 30 000 persons in the US who had survived 2 years after spinal cord injury and found no statistically significant improvements in long-term survival when comparing those injured between 1973 and 1979 with those injured in the 1980–1989 and 1990–2004 periods. In Denmark, survival improved over time from 1953–1971 to 1972–1990.[6] In terms of gender differences, studies from Denmark and Norway[6–8] have reported a higher mortality for women than for men. These findings contrast with findings from the US where male gender is associated with a significantly higher mortality than female gender.[9] A recent incidence study from Denmark showed that the incidence of TSCI is 10 per million person-years,[10] and this incidence has remained stable over the past 40 years.[11] It is unknown whether survival after TSCI has improved in Denmark during recent decades and if any gender differences exist. The present study of a hospital-based population of TSCI patients in Western Denmark aims to examine the overall survival and mortality over time (1990–1994, 1995–1999, 2000–2004, 2005–2009 and 2010–2012) adjusted for age at the time of injury and gender.

MATERIAL AND METHODS

Design and patients

The present hospital-based survival study included 686 patients with TSCI admitted to the Spinal Cord Injury Centre of Western Denmark (VCR) between 1 January 1990 and 31 December 2012. The patients who died before reaching a hospital or the rehabilitation centre were not included. The criteria for referral to the centre are spinal cord injury and residence in the catchment area, which covers a population of 3.0 million people corresponding to ~60% of the Danish population. Patients are referred regardless of their age and their

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need for ventilator support. Patients with minor motor and sensory dysfunction and patients with no rehabilitation potential are usually not referred. A total of 21 patients were excluded as they were mistakenly given a non-valid personal identification number during the data entry procedure. The patients ($N = 665$) were followed up for a minimum of 2 years and a maximum of 25 years, until death, emigration or 31 December 2014, whichever came first.

Definition of TSCI

TSCI is defined according to Kraus *et al.*[12] as an acute, traumatic lesion of the spinal cord with varying degrees of motor and/or sensory deficit or paralysis. Injury of the cauda equina was included in the definition, but isolated injury of other nerve roots was excluded. Level and completeness of TSCI was determined at the VCR, according to the International Standards for Neurological Classification of Spinal Cord Injury.[13,14] Usually this was done weeks to months after the injury using the current standards. If level or completeness of TSCI changed during the admission period, status from the discharge examination was used.

Data collection

Information about age at the time of injury, year of injury, cause of injury, level of injury and completeness of injury was obtained from VCR patient records. Data on vital status, emigration status and date of death were obtained from the Civil Registration System.[15]

Data analyses

For the survival analyses, patients were categorised according to age at the time of injury ($\leqslant 60$ and >60 years). Except for the last period, 2010–12, which comprised only 3 years, year of injury was categorised into 5-year time periods in accordance with the International Spinal Cord Injury Core Data Set:[13] 1990–94, 1995–99, 2000–04 and 2005–09. Level and completeness were categorised as paraplegia versus tetraplegia and incomplete versus complete TSCI by trained physicians at least at admission and at discharge. Causes of TSCI were categorised as transport-related injuries, falls, sports and recreational injuries and other injuries. The last category included eight people injured because of assaults.

Statistical analysis

We followed up each patient from date of admission at VCR and until death, emigration or 31 December 2014, whichever came first. The survival probabilities were estimated using the Kaplan–Meier methods. Two-year survival was estimated for the entire population, whereas 5-, 10-, 15- and 25-year survivals were estimated for subpopulations defined by year of injury. To compare mortality over time, we used Cox proportional hazard regression analysis with injury in the above-mentioned five categories and with 1990–1994 as the reference period. We estimated crude and adjusted mortality rate ratios (MRRs) with 95% confidence intervals (CI). Whether the time period had an effect on the MRR was evaluated in a test for trend. The significance level was set to $P<0.05$. Potential confounders were age and gender. The adjustment for age at the time of injury was performed by restricted cubic splines with three knots[16] to allow for a nonlinear dependency of age. Preferably, cause of injury and level and completeness of the injury should have been entered into the models as potential confounders; however, due to small numbers, this would have meant that the models would have been over-fitted.[17] The assumptions of proportional hazards were graphically examined in log-minus-log plots stratified according to each potential confounder. STATA version 13.1 was used as statistical software (StataCorp, College Station, TX, USA).

Ethics

The study was approved by the Danish Data Protection Agency (Record Number 2013–41-2131). Permission to retrieve data from patients' records and to obtain the data on vital status, emigration and date of death was given by the National Board of Health (Record Number 3-3013-702/1/ and FSEID-00001382).

RESULTS

The study population counted 665 patients with TSCI admitted to the VCR during the period from 1990 to 2012. The mean follow-up time was 12.1 (s.d.: 6.8) years corresponding to a range from 0.1 to 25.0 years. The characteristics of the study population are shown in Table 1. The number of deceased patients at 2, 5 and 10 years post injury were 29 (4%), 57 (9%) and 89 (13%), respectively. At the end of the study, that is, on 31 December 2014, a total of 136 (20%) patients had died.

Overall, the median age at admission to the VCR was 36.2 years (range 13–83 years). During the study period, the proportion of persons injured at age <30 years decreased, whereas the proportion of those aged 30–60 years and >60 years at the time of injury increased (Table 1). From the earliest time period (1990–94) to the most recent time period (2010–12), the median age at injury increased from 29.5 to 46.9 (Table 2). Simultaneously, the proportion of persons injured at age >60 years increased from 7 to 21%, and the proportion of patients with incomplete tetraplegia rose from 32 to 41% (Table 1). Transport was the overall leading cause of injury (51%); however, the proportion of persons injured because of transportation decreased from 57 to 36% during the study period. Fall-related injuries were the second leading cause (23%), and this figure rose from 11 to 34%. Sports-related injuries varied from 28% in 1995–1999 and to 9% in 2005–2009, but no consistent pattern was observed over the periods (Table 1).

The 2-year survival varied between 95 and 97% in the time period examined, except for the 2005–2009 period during which it dropped to 93%. The 2-year MRRs, adjusted for age and gender, were 0.49 (95% CI: 0.10; 2.51) in the most recent time period and 1.06 (95% CI: 0.34; 3.30) in the earliest period (Table 2). Thus, the 2-year MRRs varied throughout the study period, but no decreasing trend was observed. Similarly, the 5- and 10-year survival and MRRs varied by time period of injury, and no decrease was evident over time. Consistently, survival and MRRs were lowest for the 2005–2009 period. For the entire time period (1990–2012), the 2-, 5- and 10-year MRRs for women vs men were 1.49 (0.65; 3.42), 1.05 (0.56; 1.99) and 0.86 (0.51; 1.46), respectively. Table 3 shows the 2-, 5- and 10-year survival stratified according to age at injury; $\leqslant 60$ years versus >60 years. The number of persons injured at >60 years of age increased from 10 persons (1990–1994) to 37 persons in 2005–2009. In all time periods, the 2-, 5- and 10-year survival among those >60 years was lower than for those $\leqslant 60$ years of age. Among those >60 years, survival seemed to drop in 2005–2009 with a 2-year survival of 86.5% (95% CI:70.5; 94.1) compared with 100% (95% CI: 78.2; 100.0) in 2010–2012. The 5-year survival among those >60 years was 90.0% (95% CI: 47.3; 98.5) in 1990–1994 compared with 62.2% (95% CI:44.6; 75.6) in 2005–2009, whereas it was 100% (95% CI:78.2; 100) in the last period (2010–2012). The 10-year survival among the >60 years of age decreased from 70.0% (95% CI: 32.9; 89.2) in 1990–1994 to 33.6% (95% CI: 14.8; 53.7) in 2005–2009.

DISCUSSION

This hospital-based study on survival among TSCI patients shows that survival and mortality after TSCI has not changed considerably in Denmark during the observation period, that is, from 1990 to 2014. Mortality is higher among patients above 60 years of age at injury, and we found no consistent difference in mortality for women and men. The drop in 2-, 5- and 10-year survival in the 2005–2009 cohort can be explained by random variation as suggested by the CIs and test for trend. The drop in survival among persons >60 years in this cohort might be influenced by increasing fall-related injuries resulting in incomplete tetraplegia. Besides, comorbidity may have contributed to both increased risk of fall and risk of death in this cohort.

Table 1 Characteristics of the study population of TSCI patients (*N*=665) from Western Denmark stratified on period of injury 1990–2012

	Year of injury					
	1990–1994	*1995–1999*	*2000–2004*	*2005–2009*	*2010–2012*	*Total*
No. of TSCI patients	148	123	165	158	71	665
2-Year mortality						
Person-years at risk	289.4	242.7	326.8	304.5	140.2	1303.6
No. of deaths, *n* (%)	6 (4)	6 (5)	4 (2)	11 (7)	2 (3)	29 (4)
5-Year mortality						
Person-years at risk	713.0	589.1	795.9	727.0	262.5	3087.5[a]
No. of deaths, *n* (%)	7 (5)	9 (7)	13 (8)	23 (15)	5 (7)	57 (9)[a]
10-Year mortality						
Person-years at risk	1401.9	1140.7	1541.4	1045.7	Non-applicable	5392.2[a]
No. of deaths, *n* (%)	13 (9)	17 (14)	22 (13)	32 (20)	Non-applicable	89 (13)[a]
15-Year mortality						
Person-years at risk	2057.7	1652.3	1878.9	Non-applicable	Non-applicable	6897.1[a]
No. of deaths, *n* (%)	22 (15)	26 (21)	34 (21)	Non-applicable	Non-applicable	119 (18)[a]
20-Year mortality						
Person-years at risk	2670.9	1884.6	Non-applicable	Non-applicable	Non-applicable	7742.6[a]
No. of deaths, *n* (%)	31 (21)	28 (23)	Non-applicable	Non-applicable	Non-applicable	130 (20)[a]
25-Year mortality						
Person-years at risk	2957.5	Non-applicable	Non-applicable	Non-applicable	Non-applicable	8029.2[a]
No. of deaths, *n* (%)	37 (25)	Non-applicable	Non-applicable	Non-applicable	Non-applicable	136 (20)[a]
Gender (male), *n* (%)	122 (82)	100 (81)	137 (83)	125 (79)	62 (87)	546 (82)
Age, n (%)						
<30 Years at injury	78 (53)	53 (43)	66 (40)	45 (28)	20 (28)	262 (39)
30–60 Years at injury	60 (41)	58 (47)	72 (44)	76 (48)	36 (51)	302 (45)
>60 Years at injury	10 (7)	12 (10)	27 (16)	37 (23)	15 (21)	101 (15)
Cause of injury, n (%)						
Sport	32 (22)	35 (28)	22 (13)	14 (9)	13 (18)	116 (17)
Transport	84 (57)	65 (53)	88 (53)	73 (46)	26 (36)	336 (51)
Fall	17 (11)	15 (12)	43 (26)	55 (35)	24 (34)	154 (23)
Other	15 (10)	8 (7)	12 (7)	16 (10)	8 (11)	59 (9)
Level and completeness, n (%)						
Incomplete paraplegia	37 (25)	32 (26)	43 (26)	32 (20)	14 (20)	158 (24)
Complete paraplegia	42 (28)	36 (29)	41 (25)	39 (25)	20 (28)	178 (27)
Incomplete tetraplegia	48 (32)	37 (30)	56 (34)	62 (39)	29 (41)	232 (35)
Complete tetraplegia	21 (14)	18 (15)	23 (14)	22 (14)	6 (8)	90 (14)
Missings	0 (0)	0 (0)	2 (1)	3 (2)	2 (3)	7 (1)

Abbreviation: TSCI, traumatic spinal cord injury.
[a]Cumulated number of deaths and the cumulated analysis time at risk and under observation.

The observed 5-year survival varied between 85 and 95%, which is lower than the 95–99% range reported for comparable countries.[1] This difference may be explained by various procedures for inclusion of subjects in the study population e.g. Frankel *et al.*[2] included only those who survived the first year post injury. Similar to O´Connor *et al.*,[3] we included those who had survived the first weeks to months and were referred to rehabilitation at VCR.

A previous Danish study showed a significant decrease in TSCI patients' overall mortality from 1953 to 1990. Further, it showed that 70% of the study population were still alive 20 years post injury.[6] Our present data show that among TSCI patients injured in the 1990–1994 period, 79% were still alive 20 years post injury and 75% remained alive at 25 years. This may indicate a small improvement in survival compared with that in the previous Danish study[6] still, the estimates are somewhat imprecise, and there may be a difference between the two studies in age at the time of injury, although the inclusion of patients in the study population is similar.

The absence of a trend towards improved survival since 1990 observed in the present study is in line with the findings reported by Shavelle *et al.*[5] These data from the US on more than 30 000 patients

Table 2 2-, 5- and 10-year overall survival and mortality rate ratio (MRR) with 95% confidence interval adjusted for age and gender of injury for traumatic spinal cord injury (TSCI) patients (*N*=665) from Western Denmark 1990–2012 stratified by year of injury

Year of injury	*Median age (years)*	*Survival % (95% CI)*	*MRR*	*MRR*[a]
2 Year				
1990–1994 (*n*=148)	29.5	96.0 (91.2; 98.2)	1 (ref)	1 (ref)
1995–1999 (*n*=123)	33.8	95.1 (89.5; 97.8)	1.19 (0.39; 3.70)	1.06 (0.34; 3.30)
2000–2004 (*n*=165)	37.0	97.6 (93.7; 99.1)	0.59 (0.17; 2.10)	0.48 (0.13; 1.71)
2005–2009 (*n*=158)	43.8	93.0 (87.8; 96.1)	1.75 (0.65; 4.72)	1.22 (0.43; 3.42)
2010–2012 (*n*=71)	46.9	97.2 (89.2; 99.3)	0.69 (0.14; 3.42)	0.49 (0.10; 2.51)
Test for trend (*P*-value)[b]			0.75	0.72
Gender (woman)				1.49 (0.65; 3.42)
5 Year				
1990–1994 (*n*=148)		95.3 (90.3; 97.7)	1 (ref)	1 (ref)
1995–1999 (*n*=123)		92.7 (86.4; 96.1)	1.55 (0.58; 4.17)	1.36 (0.51; 3.68)
2000–2004 (*n*=165)		92.1 (86.8; 95.4)	1.66 (0.66; 4.16)	1.18 (0.47; 2.99)
2005–2009 (*n*=158)		85.4 (78.9; 90.1)	3.21 (1.38; 7.48)	1.90 (0.80; 4.52)
2010–2012 (*n*=71)		0.91 (0.79; 0.96)	1.86 (0.59; 5.89)	0.95 (0.29; 3.11)
Test for trend (*P*-value)[b]			0.02	0.45
Gender (woman)				1.05 (0.56; 1.99)
10 Year				
1990–1994 (*n*=148)		91.2 (85.4; 94.8)	1 (ref)	1 (ref)
1995–1999 (*n*=123)		86.2 (78.7; 91.2)	1.61 (0.78; 3.31)	1.36 (0.66; 2.80)
2000–2004 (*n*=165)		86.7 (80.5; 91.0)	1.54 (0.77; 3.05)	1.02 (0.51; 2.05)
2005–2009 (*n*=158)		0.77 (0.68; 0.83)	3.32 (1.72; 6.39)	1.91 (0.98; 3.73)
2010–2012 (*n*=71)		Non-applicable	1.87 (0.65; 5.37)	0.85 (0.29; 2.52)
Test for trend (*P*-value)[b]			0.02	0.32
Gender (woman)				0.86 (0.51; 1.46)

Abbreviations: MRR, mortality rate ratio; TSCI, traumatic spinal cord injury.
[a]Notes: adjusted for age and gender.
[b]Notes: test for trend in mortality over time.

(4021 deaths) showed no statistically significant difference in improvements in long-term survival between people injured during 1973–1979 and those injured in 1980–1989 and 1990–2004. Studies from Norway report similar findings of no change over time.[7,8] This absence across studies of improvements in survival may be explained by changes in comorbidity, environmental and behavioural factors.

In the present study, we were unable to adjust for comorbidity, environmental or behavioural factors, which may have changed over time. In addition, as we did not compare survival of our study population with that of the Danish background population, we were unable to take into account the general increase in life expectancy observed over the past decades.[18] Further, Denmark has seen substantial reforms in the rehabilitation of TSCI patients over the past decade.[19] Among others, these changes include shorter in-hospital stay and transfer of rehabilitation to local settings, for example, in the community. Thus, a number of factors besides treatment and rehabilitation may explain why mortality seems to be stable during the study period.

Males constituted 82% of all patients in our study population, and in the period from 1990 to 2012 there seems to be no consistent gender differences in 2-, 5- and 10-year survival. In contrast, a previous study from Denmark investigating trends in survival in the 1953–1990 period[6] showed a higher mortality among women than among men. It has been suggested that previously men were more seriously injured than women, whereas this difference has disappeared in more recent times, which may explain the similarity in mortality rates observed for males and females in the present study.[9,20]

DeVivo *et al*.[21] evaluated nearly 30 000 subjects and found that short- and long-term mortality following TSCI correlate with the degree of neurological impairment. In the present study, the level of injury could not be included in the final statistical model due to small numbers. Varma *et al*.[9] found that improvements in the quality of the acute care following TSCI have eliminated the level of injury as a major determinant of mortality during the acute phase. However, they propose that level and completeness may significantly affect the long-term prognosis when patients are transferred to community rehabilitation. In Denmark, the proportion of patients with incomplete tetraplegia rose during the study period as did the proportion of those injured above 60 years of age.[10] Our study may indicate a decrease in 2-, 5- and specifiable in the 10-year survival among those >60 years although the estimates were imprecise.

Our finding of an absence of any improvement in survival indicates that the time may have come to renew efforts to improve follow-up rehabilitation among TSCI patients in Denmark to enhance long-term survival after TSCI. Recently, an interview study from our centre (VCR)[22] explored patients' experiences after returning to their homes; an often expressed experience concerned lacking follow-up after hospital rehabilitation post TSCI, an experience that is echoed in statements from the Danish spinal cord injury patients' organisation.[23]

One limitation of the present study concerns the imprecision of the estimates which is due to small numbers in general and the low number of deaths in particular. Confounding cannot be ruled out as we were unable to adjust for cause of injury, level of injury and completeness of the injury or comorbidity. Thus, an increase in comorbidity among

Table 3 Overall survival and 95% CI in TSCI patients (*N*=665) from Western Denmark according to age and year of injury 1990–2012

Age (years)	*Year of injury*				
	1990–1994	*1995–1999*	*2000–2004*	*2005–2009*	*2010–2012*
⩽60					
Number of TSCI patients	138	111	138	121	56
2-Year survival	96.4 (91.5; 98.5)	95.5 (89.5; 98.1)	98.6 (94.3; 99.6)	95.0 (89.3; 97.7)	96.4 (86.5; 99.1)
5-Year survival	95.7 (90.6; 98.0)	93.7 (87.2; 96.9)	95.7 (90.6; 98.0)	92.6 (86.2; 96.1)	88.5 (73.9; 95.2)
10-Year survival	92.8 (87.0; 96.0)	88.3 (80.7; 93.0)	92.0 (86.1; 95.5)	88.7 (80.3; 93.6)	Non-applicable
>60					
Number of TSCI patients	10	12	27	37	15
2-Year survival	90.0 (47.3; 98.5)	91.7 (53.9; 98.8)	92.6 (73.5; 98.1)	86.5 (70.5; 94.1)	100.0 (78.2; 100.0)
5-Year survival	90.0 (47.3; 98.5)	83.3 (48.2; 95.6)	74.1 (53.2; 86.7)	62.2 (44.6; 75.6)	100.0 (78.2; 100.0)
10-Year survival	70.0 (32.9; 89.2)	66.7 (33.7; 86.0)	59.3 (38.6; 75.0)	33.6 (14.8; 53.7)	Non-applicable

Abbreviations: CI, confidence interval; TSCI, traumatic spinal cord injury.

TSCI patients from 1990 to 2012, for example, may have impacted mortality in recent years, thereby masking a potential improvement in survival related to treatment and rehabilitation. A major strength of the present study is its complete follow-up on the entire study sample; thus, differential loss to follow-up cannot have affected our results. We excluded 21 patients from the study population because of missing data. However, as the exclusion was unrelated to the outcome of interest, this is unlikely to have introduced selection bias.

Only those who survived the acute post-injury phase were included in this 25-year follow-up. Thus, the study is not affected by immortal time bias, and it is unlikely that our findings were masked by improvements in acute medical treatment. However, in comparison with other studies[2,4] we may find a lower long-term survival as we did not exclude persons who died within 2 years post injury.

The VCR covers 60% of the Danish population, whereas the corresponding centre in the Eastern part of Denmark covers the rest. There are only small differences in referral criteria between the two centres, and we consider the referral criteria to have been stable during the study period. Therefore, the results may be generalised to all Danish TSCI patients who survive the acute phase and are referred to initial rehabilitation.

CONCLUSION

Survival and mortality after TSCI did not change considerably during the observation period from 1990 to 2014. Furthermore, there seems to be no gender differences in mortality; however, mortality is higher among patients above than below 60 years of age at the time of injury.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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