Original Article

Lower Extremity Amputation Rate and High 10-year Mortality Rate after Spinal Cord Injury in Taiwan: A Population-Based Longitudinal Study

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Background/Objective: Mortality and disability rates are high among patients with spinal cord injury (SCI). Identifying the comorbidities that might increase mortality rate after SCI is the key to the prompt implementation of suitable prevention strategies. We examined patient mortality and extremity amputation rates following SCI. In addition, we evaluated comorbidities associated with mortality after SCI.

Design: Population-based cohort study

Setting: Analysis of the Taiwan National Health Insurance Research Database (NHIRD)

Patients or Participants: We identified patients with SCI between January 1, 1997 and December 31, 2013 from the NHIRD and included them in the study cohort. All patients were followed up until death, withdrawal from the National Health Insurance program, or December 31, 2013, whichever came first.

Results: Amputation surgery of extremities was performed on 224 (1.74%) patients with SCI. The mortality rate was 32.92%. The most common comorbidities one year prior to death in patients with SCI were infectious disease (971/4,236, 22.92%), cancer (419/4,236, 9.89%), and intracranial hemorrhage or cerebral infarction (234/4,236, 5.52%).

Conclusion: Patients in Taiwan have a low extremity amputation rate and high mortality rate after SCI. Infectious disease, cancer, intracranial hemorrhage, and cerebral infarction are the most common comorbidities in patients with SCI in Taiwan.

Key words: spinal cord, mortality, amputation rate

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Introduction

Individuals with spinal cord injury (SCI) have a significantly reduced life expectancy.[1] Life expectancy following SCI improved significantly after World War II owing to advances in medicine, emergency services, and life-long care.[2-6] Although medical care has improved, SCI still leads to numerous physiological disorders and a range of complications in various body systems.[7,8] These severe comorbidities cause SCI mortality rate to remain high.[8,9]

Previous studies have reported that mortality rate is the highest in the first 2 years following SCI.[10-13] The mortality rate of patients with SCI has reached approximately three times that of healthy individuals.[8] Factors such as age (older), comorbidities (more),[14] neurological level, and extent of SCI[8] have been reported to be correlated with survival rate.

High mortality rates following SCI have been reported in Europe.[15] Country-specific and cross-country studies have been conducted to collect information for making relevant health policies to improve primary and secondary prevention and care . Therefore, investigating the comorbidities that might increase mortality rate after SCI is crucial to promptly implement suitable prevention strategies. Moreover, there is a lack of literature on SCI-induced mortality in Taiwan. Therefore, our data can be more broadly applied to research on injury surveillance. We evaluated comorbidities and explored the causes of long-term death among individuals with SCI.

In addition, distinct levels of SCI severity might result in dissimilar levels of physical disability. Tetraplegia occurs in 54% of patients with cervical SCI. Paraplegia was observed in approximately 45% of patients with thoracic and lumbar SCI. Only 1% of patients were discharged with a normal physical status.[17] The percentages per disability were reported as follows: incomplete tetraplegia (34.7%), incomplete paraplegia (23.0%), complete tetraplegia (18.5%), and complete paraplegia (18.5%).[17] These patients must live the remainder of their lives with nonfunctional limbs. Our aim was to determine the risk of loss of those limbs in patients with SCI by calculating the extremity amputation rate on the basis of a long-term follow-up.

To answer this question, we conducted a population-based retrospective study including patients from the Taiwan National Health Insurance Research Database (NHIRD) over a 10-year follow-up period. We examined the mortality rate and amputation rate for extremities in patients with SCI. In addition, we used the patients' background data to evaluate the comorbidities in those who died from SCI.

Materials and Methods

Data source

This retrospective population-based cohort study used data from the Longitudinal National Health Research Institute Data (NHIRD). The Taiwan National Health Research Institute (NHRI) covers the medical claims of 22.9 million residents, who comprise > 99% of the total population of Taiwan. The NHRI released the claims data of all NHI beneficiaries for public use through the NHIRD. The NHIRD covers claims data from 1997 to 2013. We used a data set that includes all records of adult patients who had received orthopedic-related surgeries from the NHIRD. The completeness and accuracy of the NHIRD data are ensured by the Department of Health and the National Health Insurance Bureau of Taiwan. The medical records of the beneficiaries released by the insurance authority are encrypted secondary data and can be used for research purposes. Therefore, this study was exempted of an ethics review.

All sampled individuals were followed up for outcome identification using the International Classification of Diseases, Ninth

Table 1. Characteristics of patients with spinal cord injury.

	N = 12,868	Female (N = 5,618)	Male (N = 7,250)	*p* value
Age	53.09 ± 19.51	58.90 ± 18.66	48.59 ± 18.80	< 0.0001
Age Group				< 0.0001
< 20	477 (3.71)	138 (2.46)	339 (4.68)	
20 – 39	3,331 (25.89)	935 (16.64)	2,396 (33.05)	
40 – 59	3,686 (28.64)	1,422 (25.31)	2,264 (31.23)	
60 – 79	4,435 (34.47)	2,501 (44.52)	1,934 (26.68)	
≥ 80	939 (7.30)	622 (11.07)	317 (4.37)	
Type				< 0 .0001
Cervical	4,067 (31.61)	1,111 (19.78)	2,956 (40.77)	
Thoracic	2,382 (18.51)	1,368 (24.35)	1,014 (13.99)	
Lumbar	5,638 (43.81)	2,879 (51.25)	2,759 (38.06)	
Other	781 (6.07)	260 (4.63)	521 (7.19)	
Comorbidities				
Myocardial infarct	113 (0.88)	50 (0.89)	63 (0.87)	0.8991
Congestive heart failure	479 (3.72)	291 (5.18)	188 (2.59)	< 0.0001
Peripheral vascular disease	109 (0.85)	52 (0.93)	57 (0.79)	0.3922
Cerebrovascular disease	1,119 (8.70)	609 (10.84)	510 (7.03)	< 0.0001
Dementia	242 (1.88)	139 (2.47)	103 (1.42)	< 0.0001
Chronic lung disease	545 (4.24)	201 (3.58)	344 (4.74)	0.0011
Connective tissue disease	163 (1.27)	105 (1.87)	58 (0.80)	< 0.0001
Ulcer	2,184 (16.97)	1,112 (19.79)	1,072 (14.79)	< 0.0001
Chronic liver disease	929 (7.22)	370 (6.59)	559 (7.71)	0.0145
Diabetes	999 (7.76)	596 (10.61)	403 (5.56)	< 0.0001
Diabetes with end organ damage	382 (2.97)	247 (4.40)	135 (1.86)	< 0.0001
Hemiplegia	297 (2.31)	96 (1.71)	201 (2.77)	< 0.0001
Moderate or severe kidney disease	354 (2.75)	167 (2.97)	187 (2.58)	0.1761
Tumor, leukemia, lymphoma	313 (2.43)	153 (2.72)	160 (2.21)	0.0593
Moderate or severe liver disease	51 (0.40)	10 (0.18)	41 (0.57)	0.0005
Malignant tumor, metastasis	45 (0.35)	22 (0.39)	23 (0.32)	0.4785
AIDS	1 (0.01)	0 (0.00)	1 (0.01)	-
Amputation	224 (1.74)	76 (1.35)	148 (2.04)	0.0031
Death	4,236 (32.92)	1,991 (35.44)	2,245 (30.97)	< 0.0001

Revision, Clinical Modification (ICD-9-CM) codes. This study was approved by the Institutional Review Board of E-Da Hospital (EMRP-103-011; EMRP-103-012) and Taiwan NHRI (NHIRD-103-116). This study was exempted from undergoing a full review by the Institutional Review Board of E-Da Hospital.

Definition of the study cohort and outcomes

We identified patients with SCI between January 1, 1997 and December 31, 2013 from the NHIRD and included them in the study cohort. SCI was categorized into cervical, thoracic, lumbosacral, and multilevel types. We used ICD-9-CM codes, which were identified from the first diagnosis of SCI during in-patient stays. The corresponding ICD-9-CM codes are presented in Appendix 1. We defined amputation surgery of extremities as those performed after the index days. The types of extremity amputation surgery included those at the thigh, leg, ankle, toe, arm, forearm, wrist, and finger level; disarticulation at the shoulder, elbow, wrist, finger, hip, knee, ankle, and toe level; hemipelectomy; and four-corner amputation of the shoulder. The amputation was determined according to the levels of SCI. The mortality rates after the index day were also calculated in this study. The baseline characteristics of all patients were stratified according to gender. The effects of gender and age on mortality

rates were also analyzed. Comorbidities were classified from one year prior to mortality. All patients in this study were followed up until death, withdrawal from the National Health Insurance program, or December 31, 2012, whichever came first.

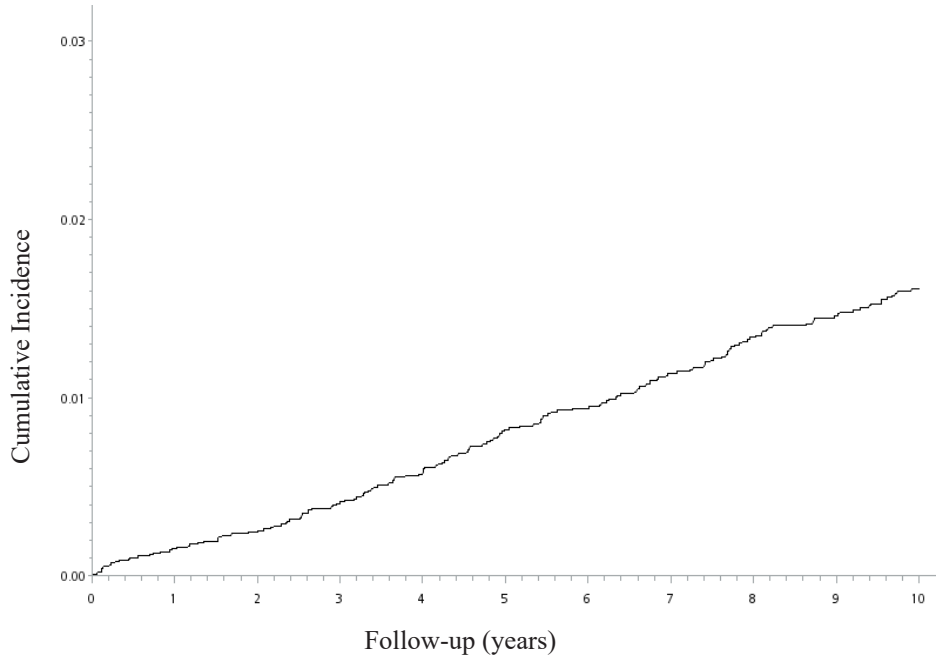
Statistical analysis

T-test was used to compare qualitative data. Survival rate was evaluated using the Kaplan–Meier method. Influences of gender and age were analyzed using the chi-square test. All statistical tests were performed using SAS Version 9.4 (SAS Institute, Cary, NC, USA).

Results

Patient baseline characteristics

A total of 12,868 patients with SCI were enrolled in the study. Of all the patients, 7,250 (56.34%) were men and 5,618 (43.66%) were women. Among them, 4,067 (31.61%) had SCI at the cervical level, 2,382 (18.51%) had SCI at the thoracic level, 5,638 (43.81%) had SCI at the lumbosacral level, and 781 (6.07%) had



Year	Start	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Number of Patients	12,868	12,002	11,468	10,990	10,534	10,143	9,797	9,453	9,106	8,789	58

	1st	2nd	3rd
Cumulative incidence (95% CI)	0.0088 (0.0077 – 0.01)	0.0139 (0.0125 – 0.0155)	0.0196 (0.0179 – 0.0215)
	4th	5th	6th
Cumulative incidence (95% CI)	0.0242 (0.0223 – 0.0263)	0.029 (0.0268 – 0.0313)	0.0328 (0.0304 – 0.0354)
	7th	8th	9th
Cumulative incidence (95% CI)	0.0375 (0.0348 – 0.0404)	0.0419 (0.0389 – 0.0451)	0.0455 (0.0423 – 0.049)
	10th		
Cumulative incidence (95% CI)	0.0486 (0.0451 – 0.0523)		

Fig. 1 Cumulated incidence of mortality in patients with spinal cord injury.

Table 2. Incidence of amputation of the extremities corresponding to different levels spinal cord injury.

	Cervical	Thoracic	Lumbar	Other
Thigh	16	12	13	5
Leg, forearm	25	11	26	4
Digit, toe	24	17	34	7
Digit, toe disarticulation	0	2	2	0
Hip disarticulation	3	5	3	2
Shoulder disarticulation	0	0	1	0
Hemipelvectomy	0	1	0	0
Wrist, ankle	3	2	3	0
Knee disarticulation	1	1	0	0
Ankle disarticulation	0	0	1	0
Total	72	51	83	18

SCI at multiple levels.

Most patients with SCI were between the ages of 20 and 59 years in male patients and between the ages of 60 and 79 years in female patients. The most common injuries were at the cervical (40.77%) and lumbosacral levels (38.06%) in male patients and at the lumbosacral level (51.25%) in female patients. The baseline characteristics of all patients with SCI are listed in Table 1.

Amputation rates in patients with SCI

Extremity amputation surgery was performed on 224 (1.74%) patients with SCI during the follow-up period. Of the 224 patients, 72 (32.14%) had SCI at the cervical level, 51 (22.77%) had SCI at the thoracic level, 83 (37.05%) had SCI at the lumbosacral level, and 18 (8.04%) had SCI at multiple levels. The amputation levels in all patients are listed in Table 2.

Mortality rates and comorbidities one year before death in patients with SCI

Of the study participants, 4,236 (32.92%) died after SCI during the follow-up period. The 10-year mortality rate of patients is presented in Fig. 1. The cumulated incidence of mortality increased from 0.88% (95% confidence interval [CI]: 0. 77% – 1%) in the first year after SCI to 4.86% (95% CI: 4.51% – 5.23%) 10 years after SCI. Among patients older than 19 years, male patients had a significantly higher mortality rate than female patients (Table 3). Older patients had a higher mortality rate in both the male and female groups.

For the 4,236 patients who died, comorbidities existed one year prior to mortality. The comorbidities are listed in Table 4. The most common comorbidity one year prior to death in patients with SCI was infectious disease (971/4,236, 22.92%). Pneumonia, septicemia, and urinary tract infection were three common infectious diseases in patients with SCI. The second most common comorbidity one year prior to mortality in patients with SCI

Table 3. Mortality rates in various gender and age groups.

	Female (N = 5,618)	Male (N = 7,250)	*p* value
Age Group			
< 20	11/138 (7.97%)	34/339 (10.03%)	0.4855
20 – 39	107/935 (11.44%)	416/2,396 (17.36%)	< 0.0001
40 – 59	206/1,422 (14.49%)	491/2,264 (21.69%)	< 0.0001
60 – 79	1,152/2,501 (46.06%)	1,023/1,934 (52.90%)	< 0.0001
≥ 80	515/622 (82.80%)	281/317 (88.64%)	0.0184

was cancer (419/4,236, 9.89%). Intracranial hemorrhage and cerebral infarction were the third most common comorbidities (234/4,236, 5.52%).

Decubitus ulcer (44/4,236, 1.04%) was not often treated. Only three patients (0.07%) with pulmonary embolism received treatment.

Discussion

Patients with SCI must live with nonfunctional limbs. Associated disabilities include incomplete tetraplegia (34.7%), incomplete paraplegia (23.0%), complete tetraplegia (18.5%), and complete paraplegia (18.5%).[17] Only 1% of patients were discharged with a normal physical status.[17] After long-term disability, physical complications in the extremities such as pressure ulcers,[18] osteoporosis and fractures,[19,20] heterotopic ossification,[21,22] and musculoskeletal pain[23,24] can occur.

Pressure ulcers after SCI occurred in 50% of patients with chronic SCI,[18] and the most common locations for these pressure ulcers were on the sacrum (26%), ischium (23%), heel (12%), and trochanter (10%). Bone mineral loss reached approximately 30% in the femoral shaft and 50% in the proximal tibia in patients with chronic SCI.[20] The osteoporotic condition of patients with chronic SCI led to a higher risk of extremity fractures. The incidence of lower-extremity fractures after SCI was approximately 1% – 2%.[20] Those physical complications could result in amputation surgery of the extremities in patients with chronic SCI. However, our study revealed an amputation rate of only 1.74% in patients with SCI, which is as low as the periprosthic joint infection rate in patients after total knee arthroplasty.[25] Most patients with SCI live with disability of the extremities.

The life expectancy following traumatic SCI has improved significantly since World War II owing to advances in medicine, emergency services, and life-long care.[2-6] However, the mortality rate in patients with SCI is still approximately three times that of healthy individuals.[8] Liis[1] reported that the mortality rate was 27.23% in Estonia. Savic[6] reported that the mortality rate reached 42.3% in a 70-year study conducted in the United Kingdom. Our study indicated that the mortality rate in patients with SCI reached 32.92% in Taiwan after 10 years of follow-up. This high mortality rate was similar to the 5-year cancer death rate (33%) reported by Rebecca in 2019.[26]

Our study revealed that male patients had a significantly higher mortality rate than female patients and that older patients had higher mortality rates. Apart from age and gender, the health conditions after SCI are also commonly regarded as major determinants of disability, reduced life satisfaction, emotional well-being,[27] and mortality and diminished life expectancy.[28] Investigating the comorbidities that might increase mortality rate after SCI is crucial for prompt implementation of suitable prevention strategies. Country-specific and cross-country studies have been conducted to collect information for making relevant health policies to improve primary and secondary prevention and care.[16]

Conventional and frequent "secondary" health comobidities include chronic nociceptive and neuropathic pain, spasticity, urinary tract and pulmonary infections, circulatory problems, osteoporosis and related fractures, bowel and bladder regulation problems, sexual dysfunction, and pressure ulcers.[29,30] In addition, SCI may incur an increased risk of chronic diseases associated with the general aging process, including cardiovascular disease, diabetes, cancer, and depression.[30] Martin reported that spasticity, chronic pain, and sexual dysfunction are most frequently observed in patients with SCI.[31] Savic conducted a retrospective 70-year study focusing on the causes of death after traumatic SCI in the UK population.[6] He reported that the most frequent causes of death were respira-

tory problems (29.3%), circulatory problems (including cardiovascular and cerebrovascular diseases) (26.7%), neoplasms (13.9%), urogenital problems (11.5%), digestive problems (5.3%), and external causes (including suicide) (4.5%). Our study retrospectively evaluated the comorbidities present within one year before mortality in patients with SCI. The result indicated that infectious diseases (22.92%) were the most frequently observed comorbidity in patients. Among infectious diseases, pneumonia, septicemia, and urinary tract infection were the three most common diseases. The second most common comorbidity was cancer (9.89%), followed by intracranial hemorrhage and cerebral infarction (5.52%). The might be useful information to reference when implementing proper policies for reducing the mortality rate of patients with SCI in Taiwan in the future.

Our study has some limitations that should be addressed. First, laboratory and pathological data were unavailable in the NHIRD. Therefore, we could not determine the severity of comorbidities. Second, we could not evaluate the physical conditions of these patients. Furthermore, we did not know the exact severity level or location of SCI. In addition, we could not examine the potential influences of body weight or cigarette smoking, alcohol drinking, and dietary habits because this information was unavailable in the NHIRD. Given that, for the purpose of privacy protection, linking the NHIRD with external data is strictly prohibited, we could not acquire direct information on these factors. However, the NHIRD represents all residents of Taiwan. Our study has the merit of no loss of follow-up, particularly caused by convenient hospital travel.

In conclusion, there is a low extremity amputation rate and high mortality rate after SCI among patients in Taiwan. Infectious diseases, cancers, intracranial hemorrhage, and cerebral infarction are the most common comorbidities in patients with SCI in Taiwan.

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Supplementary Material

Appendix 1. ICD-9-CM codes and the corresponding diseases or procedures.

Disease or procedures	Corresponding ICD-9-CM codes
Cervical cord injury	806.0; 806.1; 952.0 806.0x (x = 0 – 9) 806.1x (x = 0 – 9) 952.0x (x = 0 – 9)
Thoracic cord injury	806.2; 806.3; 952.1 806.2x (x = 0 – 9) 806.3x (x = 0 – 9) 952.1x (x = 0 – 9)
Lumbar and sacral cord injury	806.4; 806.5; 806.6; 806.7 806.6x (x = 0,1,2,9) 806.7x (x = 0,1,2,9) 952.x (x = 2,3,4)
Multiple locations	952.8; 952.9
Amputation	
Thigh	64022B
Leg; arm; forearm	64023B
Wrist; ankle	64024B
Finger; toe	64025C
Disarticulation	
Shoulder	64185B
Elbow	64059B
Wrist	64060B
Knee	64061B
Hip	64184B
Ankle	64062B
Finger; toe	64063C
Hemipelvectomy	64148B
Four corner amputation of shoulder	64209B

Footnotes: ICD-9-CM, International Classification of Diseases, 9th Revision, Clinical Modification.