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Original Article

Increased Risk of Arrhythmia in Patients with Cervical Spinal Cord Injury: A Nationwide Population-based Matched Cohort Study

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Objective: To investigate the risk of cardiac arrhythmias among adults with spinal cord injury (SCI).

Methods: This is a retrospective population-based matched cohort study. Data were derived from the National Health Insurance Research Database. This study identified all patients diagnosed with SCI from January 1, 2000 to December 31, 2013. Patients with SCI were categorized into the cervical SCI (C-SCI) and other SCI (O-SCI) groups according to the level of injury. The cumulative incidence of cardiac arrhythmias was compared between patients with C-SCI, those with O-SCI, and those without SCI. Cox proportional hazards regression model was used to assess the differences in the incidence of cardiac arrhythmias between C-SCI and O-SCI groups.

Results: The cumulative incidence of arrhythmia was higher in the C-SCI group than the O-SCI group or non-SCI group (log-rank p <0.0001). The C-SCI group had a higher risk of arrhythmia than the O-SCI group (adjusted hazard ratio = 1.64(95% CI 1.29-2.08, p < 0.0001). Other factors associated with arrhythmia included age, hyperlipidemia, hypertension, and chronic obstructive pulmonary disease. The incidence rate ratios (IRR) of three different types of cardiac arrhythmia were significantly higher in the C-SCI group than in the O-SCI group (supraventricular arrhythmia IRR = 3.65, 95% CI 2.23-5.99; ventricular arrhythmia IRR = 5.00, 95% CI 1.10-22.82; other arrhythmia IRR = 4.15, 95% CI 3.17-5.45).

Conclusions: Patients with C-SCI had a higher risk of cardiac arrhythmia than patients with O-SCI or those without SCI. We should monitor these patients more carefully to detect the occurrence of arrhythmia. (Tw J Phys Med Rehabil 2020; 48(2): 113 - 122)

Key Words: spinal cord injury, cardiac arrhythmia, risk

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INTRODUCTION

Spinal cord injury (SCI) may cause sensory, motor, and autonomic dysfunction. Patients would have multiple acute and chronic complications, including respiratory urinary, bowel, and cardiovascular complications, spasticity, pain syndromes, pressure ulcers, and osteoporosis.[1,2] The severity of neurological impairment is strongly related to the patients' life expectancy after SCI.[3] Pulmonary and renal problems used to be the leading causes of death after SCI.[4] In recent decades, morbidity and mortality caused by cardiovascular disease have become higher in long-term SCI patients.[5] Patients with SCI have increased risk of cardiovascular disease than individuals without SCI owing to a greater prevalence of obesity, lipid disorders, metabolic syndrome, diabetes, elevated inflammatory markers, chronic immobilization, and autonomic dysfunction.[6] Among the above mentioned etiologies, autonomic dysfunction would lead to cardiac arrhythmias, which are common in patients with SCI, especially in those with high-level injuries. Given that the sympathetic control of the heart originates from the first to fifth thoracic vertebra levels, the high-level spinal cord injuries may cause impaired sympathetic output with unopposed parasympathetic control and result in heart rate abnormalities.[7,8]

Although some studies have been conducted to investigate the association between the incidence of cardiac arrhythmias and SCI, the limitation of previous studies included small sample sizes and short period of observation.[8,9] If clinicians could have further information about the incidence of cardiac arrhythmias in patients with SCI, they will be able to identify high-risk patients and provide proper medical management to these patients. In this retrospective cohort study, we aimed to investigate the relationship between SCI and cardiac arrhythmias using a nationwide database. We hypothesized that cervical SCI led to higher incidence of cardiac arrhythmia than other levels of SCI.

MATERIALS AND METHODS

Research Design

This retrospective cohort study included patients with SCI from the Taiwan National Health Insurance Research Database (NHIRD). The NHI program in Taiwan covers more than 99% of approximately 23 million Taiwan residents; thus, the NHIRD is a comprehensive medical database. NHIRD contains medical data on inpatient care, date of service, diagnostic codes, pharmacy use, prescription profiles, procedures, and surgeries. This database is widely used in academic studies. The diagnosis of SCI was defined according to the Registry for Catastrophic Illness Patient Database, which is a subpart of NHIRD, from 2000 to 2013. We also sampled patients in the comparison cohort from the Longitudinal Health Insurance Database 2000 (LHID 2000), which is a database offered by the Bureau of National Health Insurance. This database contains all the original claim data of 1,000,000 individuals randomly sampled from the NHIRD in 2000. After de-identifying and encrypting data by NHIRD, we were not able to trace individual patients by using the data. Therefore, the informed consent was note required prior to study participation. We compared the risks of arrhythmia between these two cohorts. The study protocol was approved by the institutional review board which specifically waived the consent requirement.

Participants

This cohort study used NHIRD to identify all patients diagnosed with SCI between January 1, 2000 and December 31, 2013. We divided these patients into the following subgroups by neurologic level of injury according to International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes for further analysis (ICD-9-CM codes for C-SCI: 8060, 8061, 9520; ICD-9-CM codes for O-SCI: 8062, 8063, 9521, 8064, 8065, 9522, 806, 952): C-SCI and O-SCI groups. To improve the diagnostic accuracy of SCI, only patients obtained from the Registry for Catastrophic Illness Patients Database (RCIPD) diagnosed with SCI were selected. The index date of SCI was the date when *the patients were registered* for the first time. We excluded patients with the following characteristics: age<20 years, and prior history of arrhythmia (ICD-9-CM codes 427), conduction disorders (ICD-9-CM codes 426), coronary heart disease (ICD-9-CM codes 410, 411, 412, 413, 414),

coronary heart failure (ICD-9-CM codes 398, 402, 428), cerebrovascular accident (ICD-9-CM codes 433, 434, 435, 436, 437, 438) before the index date of SCI.

In the comparison (non-SCI) cohort, subjects were selected from the LHID2000. The propensity score method was used at 1:4 ratio based on age, sex, and comorbidities (1:4 case–comparison ratio). The comorbidities included hypertension (ICD-9-CM codes 401, 402, 403, 404, 405), *chronic obstructive pulmonary disease* (ICD-9-CM codes 491, 492, 496), diabetes (ICD-9-CM code 250), hyperlipidemia (ICD-9-CM code 272), chronic kidney disease (ICD-9-CM code 585), and liver cirrhosis (ICD-9-CM code 571). Only the patients with at least two consistent diagnoses of these diseases recorded in outpatient clinics within 1 year or the diagnoses recorded for at least once during hospitalization were selected. These comorbidities may affect the incidence rate of arrhythmia for patients with SCI and should be taken as confounding factors. The index date of matched subjects without SCI were assigned by the date of a random outpatient department record.

Study endpoints

Patients who had any diagnosis of arrhythmia (ICD-9-CM codes 427) in both the SCI and non-SCI groups were identified. All subjects were followed up from the index date until the incidence of arrhythmia or censored at the end of the study period or the date of withdrawal from the NHI program. The outcome was any inpatient diagnosis of arrhythmia or diagnoses of arrhythmia in the outpatient departments for at least twice within 1 year, whether the patients were alive or died after the arrhythmia events. We also classified arrhythmia into three subgroups for further analysis: supraventricular arrhythmia(ICD-9-CM codes 427.0, 427.3, 427.61, 427.81), ventricular arrhythmia(ICD-9-CM codes 427.1, 427.4), and other arrhythmia(ICD-9-CM codes 427.2, 427.5, 427.60, 427.69, 427.89, 427.9).

Statistical Analysis

The baseline characteristics between the SCI, non-SCI cohort and the distribution of cases with arrhythmia were analyzed using descriptive statistics. The Pearson's chi-squared test was used to compare the categorical variables and the independent t-test for the continuous variables. The Kaplan-Meier method was used to estimate the cumulative incidence of arrhythmia, and the log-rank test was used to evaluate the differences among the C-SCI, O-SCI, and non-SCI cohorts. Cox proportional hazards models were used to assess the risk of developing arrhythmia in patients with SCI by estimating the hazard ratio (HR), and the HRs were adjusted by many covariates, including groups, sex, age, and comorbidities.

In the subgroup analyses, we divided the SCI patients with arrhythmia into three groups (supraventricular arrhythmia, ventricular arrhythmia, and other arrhythmia) and calculated the incidence rate ratio between the C-SCI and O-SCI groups. The statistical significance was defined as p values < 0.05. All statistical analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

RESULTS

We identified 5,050 patients in the SCI group and 20,200-matched subjects in the non-SCI group 「Figure 1」. Table 1 shows a comparison of the baseline characteristics between the SCI and non-SCI groups. There was no significant difference in sex, age, or comorbidities between the SCI and non-SCI groups. There were 3567 and 1483 patients in the C-SCI and O-SCI groups, respectively. Table 2 shows the distribution of arrhythmia cases in patients with SCI. The risk of arrhythmia was higher in the C-SCI group than in the O-SCI group (9.9% vs 5.9%). Among the three types of arrhythmia, other arrhythmia was the most often diagnosed in the database, and the distribution of three types of arrhythmia was significantly different among different age groups ($p<0.0001$). Patients with SCI and arrhythmia were older and likely to have diabetes mellitus, hyperlipidemia, chronic kidney disease, hypertension, and chronic obstructive pulmonary disease. Among these patients with arrhythmia, there were 93 patients with supraventricular arrhythmia, 12 patients with ventricular arrhythmia, and 335 patients with other arrhythmia.

Table 1. Baseline characteristics of patients with and without SCI before and after matching. Abbreviations: SCI, spinal cord injury; COPD, chronic obstructive pulmonary disease

	Baseline before matching				Baseline after matching					
		Non-SCI (n=569104)	SCI (n=5050)			Non-SCI (n=20200)	SCI (n=5050)	Cervical SCI (n=3567)	Other SCI (n=1483)	
Factors	N	n(%)	n(%)	*p*-value	N	n(%)	n(%)	n(%)	n(%)	*p*-value*
Sex				<0.0001						0.8143
Female	282779	281654(49.49)	1125(22.28)		5594	4469(22.12)	1125(22.28)	720(20.19)	405(27.31)	
Male	291375	287450(50.51)	3925(77.72)		19656	15731(77.88)	3925(77.72)	2847(79.81)	1078(72.69)	
Age				<0.0001						0.9111
20-40	302106	300367(52.78)	1739(34.44)		8610	6871(34.01)	1739(34.44)	1203(33.73)	536(36.14)	
41-60	207650	205323(36.08)	2327(46.08)		11640	9313(46.10)	2327(46.08)	1699(47.63)	628(42.35)	
61-80	56785	55879(9.82)	906(17.94)		4601	3695(18.29)	906(17.94)	630(17.66)	276(18.61)	
>80	7613	7535(1.32)	78(1.54)		399	321(1.59)	78(1.54)	35(0.98)	43(2.90)	
Comorbidity										
Diabetes mellitus	79773	78439(13.78)	1334(26.42)	<0.0001	6678	5344(26.46)	1334(26.42)	976(27.36)	358(24.14)	0.9545
Hyperlipidemia	130505	129192(22.70)	1313(26.00)	<0.0001	6618	5305(26.26)	1313(26.00)	978(27.42)	335(22.59)	0.7045
Chronic kidney disease	12965	12604(2.21)	361(7.15)	<0.0001	1727	1366(6.76)	361(7.15)	261(7.32)	100(6.74)	0.3309
Liver cirrhosis	12587	12324(2.17)	263(5.21)	<0.0001	1286	1023(5.06)	263(5.21)	170(4.77)	93(6.27)	0.6781
Hypertension	122975	121114(21.28)	1861(36.85)	<0.0001	9310	7449(36.88)	1861(36.85)	1335(37.43)	526(35.47)	0.9740
COPD	81319	79854(14.03)	1465(29.01)	<0.0001	7324	5859(29.00)	1465(29.01)	1137(31.88)	328(22.12)	0.9945

* Non-SCI compared with SCI.

Table 2. Distribution of cases with arrhythmia in patients with SCI. Abbreviations: SCI, spinal cord injury; COPD, chronic obstructive pulmonary disease

				Arrhythmia			
	No arrhythmia (n=4610)	Arrhythmia (n=440)		Supraventricular arrythmia (n=93)	Ventricular arrhythmia (n=12)	Other arrhythmia (n=335)	
Variables	n (%)	n (%)	p-value[#]	n (%)	n (%)	n (%)	p-value[$]
Level of SCI			<0.0001***				0.8703
Cervical	3214 (69.72)	353 (80.23)		73 (78.49)	10 (83.33)	270 (80.60)	
Other	1396 (30.28)	87 (19.77)		20 (21.51)	2 (16.67)	65 (19.40)	
Sex			0.1060				0.4484
Female	1013 (21.97)	112 (25.45)		20 (21.51)	2 (16.67)	90 (26.87)	
Male	3597 (78.03)	328 (74.55)		73 (78.49)	10 (83.33)	245 (73.13)	
Age			<0.0001***				<0.0001***
20-40	1630 (35.36)	109 (24.77)		16 (17.20)	3 (25.00)	90 (26.87)	
41-60	2132 (46.25)	195 (44.32)		36 (38.71)	6 (50.00)	153 (45.67)	
61-80	780 (16.92)	126 (28.64)		31 (33.33)	3 (25.00)	92 (27.46)	
>80	68 (1.48)	10 (2.27)		10 (10.75)	0 (0.00)	0 (0.00)	
Comorbidity							
Diabetes mellitus	1180 (25.60)	154 (35.00)	<0.0001***	41 (44.09)	3 (25.00)	110 (32.84)	0.1007
Hyperlipidemia	1142 (24.77)	171 (38.86)	<0.0001***	39 (41.94)	5 (41.67)	127 (37.91)	0.7645
Chronic kidney disease	317 (6.88)	44 (10.00)	0.0196*	13 (13.98)	2 (16.67)	29 (8.66)	0.2346
Liver cirrhosis	235 (5.10)	28 (6.36)	0.3032	6 (6.45)	1 (8.33)	21 (6.27)	0.9587
Hypertension	1610 (34.92)	251 (57.05)	<0.0001***	55 (59.14)	7 (58.33)	189 (56.42)	0.8921
COPD	1257 (27.27)	208 (47.27)	<0.0001***	54 (58.06)	4 (33.33)	150 (44.78)	0.0469*

Abbreviations: COPD, chronic obstructive pulmonary disease.

Comparisons between no arrhythmia and arrhythmia.

$ Comparisons among supraventricular arrhythmia, ventricular arrhythmia, and other arrhythmia.

*p-value < 0.05, **p-value < 0.01, ***p-value < 0.001.

Table 3. Hazard ratios of arrhythmia in relation to selected variables in patients with SCI. Abbreviations: SCI, spinal cord injury; HR, hazard ratio; COPD, chronic obstructive pulmonary disease.

Variables	Crude HR	95% CI	p-value	Adjusted HR	95% CI	p-value
Group						
Other SCI	1	(reference)		1	(reference)	
Cervical SCI	1.68	(1.33 , 2.13)	<0.0001***	1.64	(1.29 , 2.08)	<0.0001***
Sex						
Female	1	(reference)		1	(reference)	
Male	0.88	(0.71 , 1.09)	0.2398	0.87	(0.70 , 1.08)	0.2167
Age (year)						
20-40	1	(reference)		1	(reference)	
41-60	1.51	(1.20 , 1.91)	0.0005***	1.24	(0.98 , 1.58)	0.0793
61-80	2.88	(2.23 , 3.73)	<0.0001***	2.02	(1.53 , 2.67)	<0.0001***
>80	3.50	(1.83 , 6.70)	0.0001***	2.77	(1.43 , 5.37)	0.0026**
Comorbidity						
Diabetes mellitus	1.41	(1.16 , 1.72)	0.0005***	0.88	(0.71 , 1.10)	0.2520
Hyperlipidemia	1.71	(1.41 , 2.07)	<0.0001***	1.37	(1.11 , 1.69)	0.0035**
Chronic kidney disease	1.31	(0.96 , 1.78)	0.0928	0.92	(0.67 , 1.27)	0.6125
Liver cirrhosis	1.32	(0.90 , 1.94)	0.1513	1.16	(0.79 , 1.70)	0.4564
Hypertension	2.14	(1.78 , 2.59)	<0.0001***	1.61	(1.30 , 1.98)	<0.0001***
COPD	2.10	(1.75 , 2.54)	<0.0001***	1.63	(1.34 , 1.98)	<0.0001***

Table 4. Incidence rate of each type of arrhythmia between C-SCI and O-SCI. IR: per 1000 person-years. Abbreviations: C-SCI, cervical spinal cord injury; O-SCI, other spinal cord injury; IR, incidence rate; IRR, incidence rate ratio; CI, confidence interval.

C-SCI						
Types of arrhythmia	Event	Person-Year	IR	95% CI	IRR[a]	95% CI
Supraventricular arrhythmia	73	26317.13	2.77	(2.21 , 3.49)	1.20	(0.93 , 1.54)
Ventricular arrhythmia	10	26317.13	0.38	(0.20 , 0.71)	1.14	(0.58 , 2.26)
Other arrhythmia	270	26317.13	10.26	(9.11 , 11.55)	1.12	(0.98 , 1.27)
O-SCI						
Types of arrhythmia	Event	Person-Year	IR	95% CI	IRR[b]	95% CI
Supraventricular arrhythmia	20	10924.71	1.83	(1.18 , 2.84)	0.79	(0.50 , 1.24)
Ventricular arrhythmia	2	10924.71	0.18	(0.05 , 0.73)	0.55	(0.13 , 2.26)
Other arrhythmia	65	10924.71	5.95	(4.67 , 7.58)	0.65	(0.50 , 0.83)
Non-SCI						
Types of arrhythmia	Event	Person-Year	IR	95% CI		
Supraventricular arrhythmia	334	144134.7	2.32	(2.08 , 2.58)		
Ventricular arrhythmia	48	144134.7	0.33	(0.25 , 0.44)		
Other arrhythmia	1324	144134.7	9.19	(8.71 , 9.69)		

[a]C-SCI versus Non-SCI; [b]O-SCI versus Non-SCI

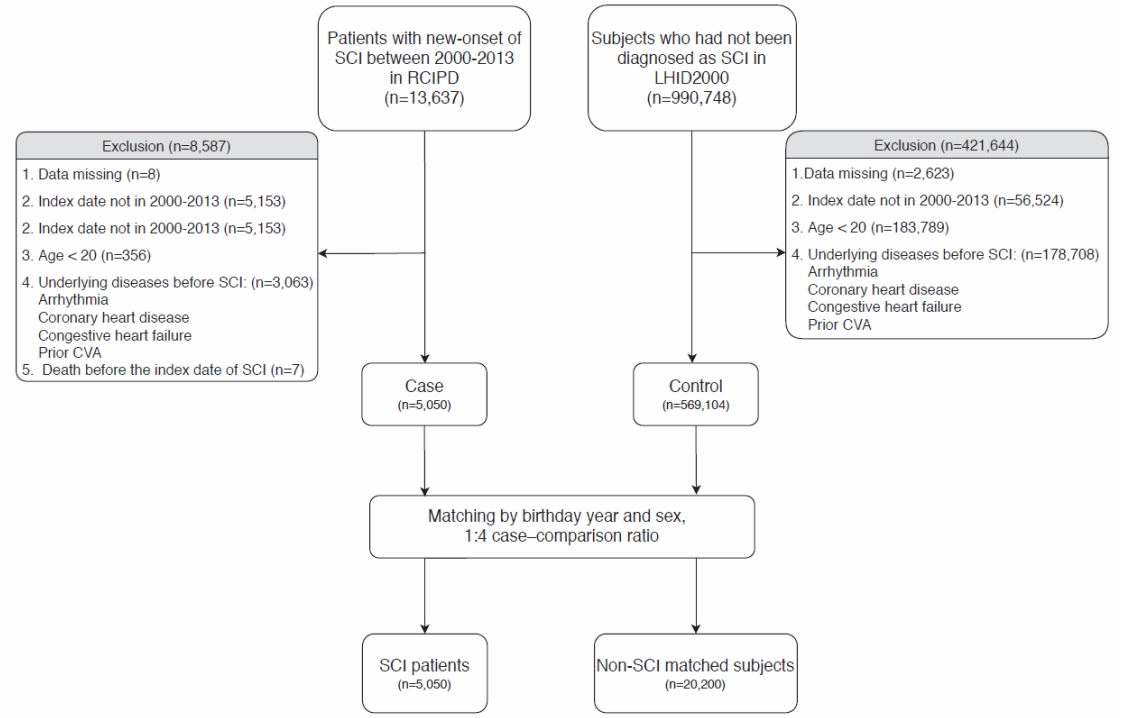

Figure 1. Flow chart of the subjects. Abbreviations: LHID, Longitudinal Health Insurance Database; SCI, spinal cord injury; CVA, cerebrovascular accident; RCIPD, Registry for Catastrophic Illness Patients Database.

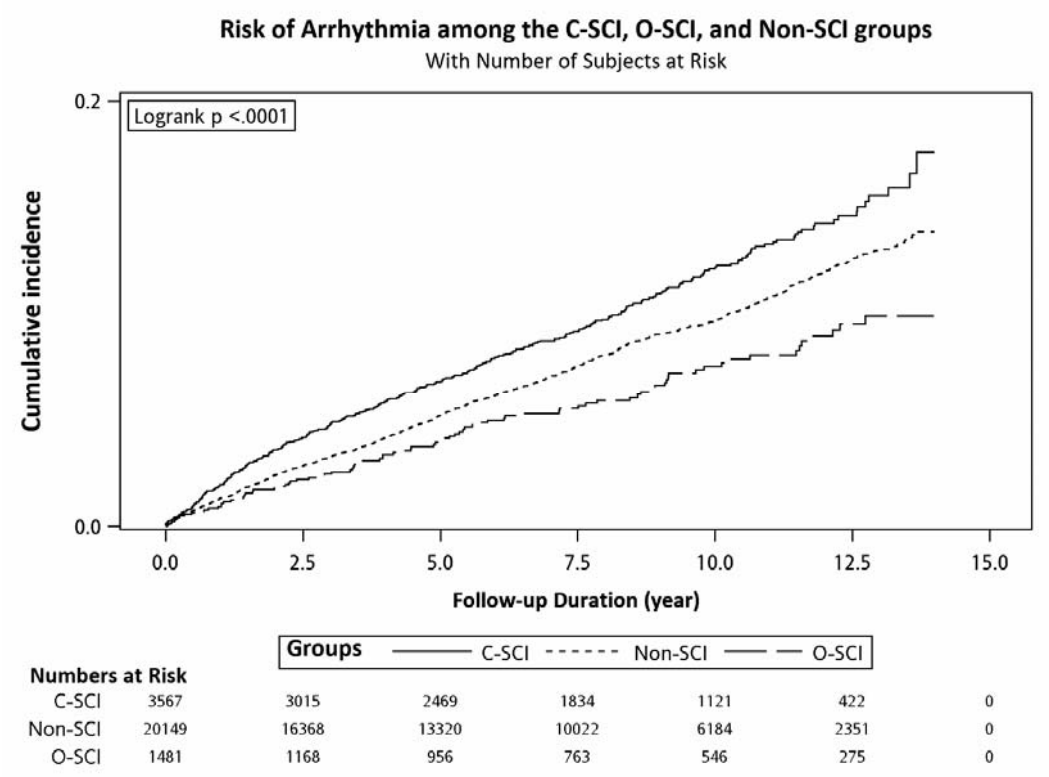

Figure 2. Comparisons of the Kaplan-Meier survival curves between the C-SCI, O-SCI, and non-SCI groups. Abbreviations: C-SCI, cervical spinal cord injury; O-SCI, other spinal cord injury; non-SCI, non-spinal cord injury.

Figure 2 presented the Kaplan–Meier curve for cumulative incidence of arrhythmia among the C-SCI, O-SCI, and non-SCI groups. Log-rank test revealed a significantly higher cumulative incidence of arrhythmia in the C-SCI group than in the O-SCI or non-SCI groups ($p < 0.0001$). Multiple comparisons adjusted by Bonferroni correction for the log-rank test showed significant difference between the C-SCI and non-SCI groups ($p < 0.0001$) and between the C-SCI and O-SCI groups ($p = 0.0048$), but not between the O-SCI and non-SCI groups ($p > 0.9999$). Table 3 presented results from the Cox proportional hazards models, stratified by groups, sex, age, and comorbidities, in patients with SCI. In patients with C-SCI, the adjusted hazard ratio (aHR) for arrhythmia versus that of the O-SCI group was 1.64(95% CI 1.29-2.08, $p < 0.0001$). There was no statistical difference in the risk of arrhythmia between male and female groups. Age stratification showed that older patients have a higher risk for arrhythmia (61-80 years: aHR = 2.02, 95% CI 1.53-2.67, $p < 0.0001$; >80 years: aHR = 2.77, 95% CI 1.43-5.37, $p= 0.0026$; all versus 20-40 years). In the analysis of comorbidities, the aHRs of arrhythmia in patients with hyperlipidemia, hypertension and chronic obstructive pulmonary disease were 1.37 (95% CI 1.11-1.69, $p = 0.0035$), 1.61 (95% CI 1.30-1.98, $p < 0.0001$), and 1.63 (95% CI 1.34-1.98, $p < 0.0001$), respectively.

In Table 4, we compared the incidence rate of different types of arrhythmia between the C-SCI, O-SCI and Non-SCI groups. The incidence rate ratio of supraventricular arrhythmia, ventricular arrhythmia, and other arrhythmia between the C-SCI and Non-SCI groups were 1.20 (95% CI 0.93-1.54), 1.14 (95% CI 0.58-2.26), and 1.12 (95% CI 0.98-1.27), respectively. And the incidence rate ratio of supraventricular arrhythmia, ventricular arrhythmia, and other arrhythmia between the O-SCI and Non-SCI groups were 0.79 (95% CI 0.50-1.24), 0.55 (95% CI 0.13-2.26), and 0.65 (95% CI 0.50-0.83), respectively.

DISCUSSION

We included 3567 and 1483 patients in the C-SCI and O-SCI groups. We only selected patients from the Registry for Catastrophic Illness Patients Database for better diagnostic accuracy. Patients with mild muscle weakness, such as mild quadriparesis or paraparesis, were not registered in this database. As a result, many patients with thoracic or lumbar spinal cord injury would not be sampled. This may be the reason why the number of C-SCI group is much higher than O-SCI group in this study. With this method, the patients enrolled in our study were with relatively worse function in overall SCI groups.

In this study, we found that the C-SCI group has a higher risk of developing arrhythmia than O-SCI and non-SCI groups do. Furthermore, SCI patients with hypertension, hyperlipidemia and chronic obstructive pulmonary disease might potentiate the risk of arrhythmia.

Many patients with C-SCI experience arrhythmias such as bradycardia, supraventricular tachycardia, sinus node arrest, or even cardiac arrest after SCI as a result of autonomic dysfunction. According to previous studies, the incidence of persistent bradycardia (<60 beats/min) is up to 66%–100% in patients with C-SCI and 13%–33% in patients with thoracic SCI, and 10%–19% of patients with severe C-SCI (American Spinal Injury Association A) had cardiopulmonary resuscitation due to cardiac arrest.[10,11] In another study, bradycardia (<50 beats/min) was present in 17%–35% of the patients with C-SCI, and supraventricular arrhythmias were present in 23%–46% of the patients with C-SCI.[7] However, the overall cardiac arrhythmia, including supraventricular arrhythmias, ventricular arrhythmia, and other types, were found only in 9.9% of patients with C-SCI in our study. The different incidence of arrhythmia between these studies may be due to the different severities of SCI, variant ways, and timings of data acquisition.[7,8,11] In our study, the C-SCI group had a significantly higher incidence of arrhythmia than the O-SCI or non-SCI groups. It is well-known that the heart has both sympathetic and parasympathetic innervations from the autonomic nervous system. Sympathetic preganglionic neurons of the heart originate from T1–T5, and parasympathetic preganglionic neurons originate from the vagal nerve.[11,12] After high-level SCI, especially above the T5 segment, the sympathetic system of the heart is damaged, but the parasympathetic vagal tone is intact.[13] This autonomic nerve system imbalance creates vulnerability to cardiac arrhythmias. Previous studies showed that patients with both complete and

incomplete lesions are both affected by this autonomic dysfunction; however, it is thought that symptoms are less common and less severe in the latter group.[14] Although we didn't analyze the difference of incidence rate of arrhythmia between complete and incomplete lesions in this study, it is understandable that a higher proportion of patients in the C-SCI group may develop arrhythmia due to autonomic nerve system dysfunction.

In this study, aging and some comorbidities, including hyperlipidemia, hypertension, and chronic obstructive pulmonary disease, increased the risk of arrhythmia. It is well studied that aging is an independent risk factor for the development of most arrhythmias. This phenomenon may be related to structural and electrical remodeling of cardiac tissue and accrued multiple comorbidities in the elderly.[15,16] There were numerous articles investigating the role of chronic diseases in heart rhythm disorders. Hyperlipidemia, hypertension, and chronic obstructive pulmonary disease have been well established as risk factors for arrhythmias in the general population.[17-19] The relationship between these comorbidities and arrhythmia was also observed in patients with SCI in this study.

Although arrhythmia is an important complication after SCI, only one retrospective cohort study investigated the risk of atrial fibrillation after SCI.[10] In that study, patients with related ICD-9-CM codes in the hospital or outpatient medical records were included in the analysis. However, in our study, only patients diagnosed with SCI who were obtained from the RCIPD were selected in our study. The included number of participants was higher in Wang et al. than in our study, but the overall disease severity of SCI and the diagnostic accuracy might be higher in our study.[10] Wang et al. observed an increased risk of atrial fibrillation in patients with thoracic and lumbosacral spinal injuries than in patients with cervical spinal injury. According to their study, patients with thoracic and lumbosacral spinal injuries were significantly older and had higher proportions of comorbidities, which might explain why they had a higher risk for developing atrial fibrillation compared to those with cervical SCI. In our study, the incidence of arrhythmia was higher in C-SCI group than in O-SCI or non-SCI groups. And there is no statistical difference between O-SCI and non-SCI groups. This result can be explained by the more severe autonomic dysfunction in the C-SCI group, which is more reasonable and understandable.

In table 2, among C-SCI patients with arrhythmia, the prevalence of supraventricular arrhythmia seemed to be higher than ventricular arrhythmia, just like the prevalence in general population. This phenomenon may have some relationship with autonomic imbalance in C-SCI patients. In the previous studies, increased sympathetic stimulation is thought to lead to ventricular fibrillation or ventricular tachycardia.[20] In contrast, low level vagus nerve stimulation is reported to reduce ventricular arrhythmic episodes, including premature ventricular contraction and ventricular tachycardia/ventricular fibrillation.[21] As mentioned above, after high-level SCI, the patient's parasympathetic tone is higher than sympathetic tone. This fact may be the part of reason why supraventricular arrhythmia was more common than ventricular arrhythmia is C-SCI groups.

In the subgroup analysis of incidence rate ratio showed in table 4, the incidence rate of supraventricular arrhythmia, ventricular arrhythmia, and other arrhythmia in the C-SCI group seemed to be higher compared with Non-SCI group. However, it didn't reach statistical significance, which might be related to small numbers of each arrhythmic type in the subgroup analysis.

STUDY LIMITATIONS

This study nevertheless had several limitations. First, the physicians did not routinely monitor the cardiac rhythm during clinical practice; thus, some asymptomatic arrhythmia episodes were not identified and the true incidence of arrhythmia might be underestimated. Second, because of the limited information from the NHIRD in this study, we were unable to obtain individual patients' information about smoking habits, alcohol consumption, and body mass index. These data might be related to heart diseases, which could result in arrhythmia. Third, the causal relationship between SCI, arrhythmia, and other risk factors was conservatively explained in this retrospective study. Further studies are necessary to prove the causation more prudently.

CONCLUSION

Adults with C-SCI had a higher risk of cardiac arrhythmia. Given that C-SCI was an additional risk factor for arrhythmia, we should monitor these patients more carefully to detect the occurrence of arrhythmia and provide proper management.

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脊髓損傷病患心律不整風險與危險因子之探討

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本研究從健保資料庫搜尋 2000 年到 2013 年脊髓損傷的病患，比較頸髓損傷組、其他部位損傷組和對照組心律不整發生率的差異。統計發現頸髓損傷組病人心律不整的累積發病率(cumulative incidence)比其他部位損傷組和對照組還高($p<0.0001$)。其他與心律不整相關的危險因子包括年紀、性別、高血脂、慢性腎病變、高血壓、慢性阻塞性肺病。而我們也發現頸髓損傷組病人心律不整的發生率(incidence rate ratio)也比其他部位損傷組高。本篇研究結果顯示頸髓損傷組病人心律不整的風險的確比脊髓損傷在其他部位和無脊髓損傷的人高。（台灣復健醫誌 2020；48(2)：113 - 122）

關鍵詞：脊髓損傷(spinal cord injury)，心律不整(cardiac arrhythmia)，風險(risk)

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