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ARTICLE

An epidemiological study of traumatic spinal cord injuries in the fastest aging area in Japan

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Abstract

Study design Retrospective epidemiological study.

Objective To investigate the epidemiology of traumatic spinal cord injury (TSCI) in the fastest aging area in Japan.

Setting Hospitals in Akita Prefecture, Japan. Akita Prefecture has the highest ratio of people aged 65 or older in Japan (30.4% in 2012 and 34.6% in 2016).

Methods Patients with acute TSCI who required hospital treatment between 2012 and 2016 were included. The incidence of TSCI, cause, level, skeletal injury, and Frankel grade were investigated.

Results The mean annual incidence of TSCI excluding Frankel E was 86 per million (range 86–104 per million) during the 5-year study period, with a mean age of 65.9 years (male, 75.1%) and patients in their 60s as the largest age group. Cervical injury was seen in 89.8%, and cervical TSCI without skeletal injury was seen in 65.5%. Frankel D was the most common neurological deficit (53.5%). The most common cause was falls on level surfaces (32.1%), followed by low falls (21.6%) and road traffic accidents (15.6%).

Conclusions Recent incidence and characteristics of TSCI in the fastest aging society in Japan are presented. The incidence of incomplete cervical TSCI and falls on level surfaces appear to be increasing.

Introduction

Traumatic spinal cord injury (TSCI) is one of the most unfortunate events that suddenly occurs after various types of high- or low-energy trauma. Permanent motor, sensory, and autonomic dysfunction negatively impact the patient's and their families' lifestyles. In addition, recurrent complications such as urinary tract infection, pneumonia, depression, and decubitus ulcer torment them [1]. Despite much recent work, no definitive treatment, especially for patients with neurologically complete injury, has been established in the clinical setting [2, 3]. In other words, prevention of TSCI based on epidemiology is one of the main issues in this field. The incidence rate and causes of TSCI differ among countries and depend on the period. The global incidence rate ranges from 3.6 to 195.4 patients per million according to recently published articles in English [4, 5]. Generally, the most frequent cause of injury is traffic accidents in developing countries, but on the other hand, it is decreasing or stable in developed countries because of infrastructure around transport facilities. Another feature is that TSCIs due to low falls in the elderly are increasing in developed countries with aging populations [4].

In Japan, the elderly population, defined as persons aged 65 years or older, is rapidly increasing. In 2016, the number of elderly persons was 34.59 million, constituting 27.3% of the total population in Japan. The proportion of the elderly aged 65 years or older in Japan is the highest in the world. Moreover, the average life expectancy is also at the highest level in the world. In 2015, the life expectancy at birth was 87.1 years for women and 80.8 years for men [6]. Akita

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Prefecture is located in the north of Japan. The recent population in Akita Prefecture has been gradually decreasing, from 1.06 million in 2012 to 1.01 million in 2016. Conversely, the proportion of the elderly aged 65 years or older has been increasing rapidly, from 30.4% in 2012 to 34.6% in 2016. The percentage of the population of Akita Prefecture aged 65 years or older is estimated to be the same as that of the average in Japan 20 years from now. Actually, when the percentage of the population of Japan aged 65 years or older was 12.1% in 1990, the most frequent cause of TSCI was traffic accidents (43.7%), followed by falls from heights (28.9%) between 1990 and 1992, and the estimated incidence rate of TSCI was 40.2 per million, with a main peak at 59 years of age, and an additional small peak at 20 years of age according to a nationwide epidemiological survey that was conducted by the Japan Medical Society of Spinal Cord Lesion [7]. According to a recent epidemiological study in a rural area of Japan in 2011 and 2012 by Katoh et al. [8], the estimated incidence rate of TSCI was 121.4 per million and 117.1 per million, respectively, with a main peak in the eighth decade when the percentage of people aged 65 years or older was 27.0% in this area in 2011. More interestingly, falls on level surfaces and low falls were the most frequent and accounted for more than half of the causes of cervical spinal cord injury (SCI) without skeletal injury. These results suggest that falls are the most common causes of TSCI in an aging society.

Thus, epidemiological study of TSCI in the fastest aging society is considered to be quite important. The purpose of this study was to investigate the current demographic and epidemiological characteristics of patients with TSCI in Akita Prefecture, which is the fastest aging area in Japan.

Methods

We hypothesized that an increase in the incidence of TSCI, especially incomplete cervical SCI, is related to aging of the population. In this retrospective epidemiological study, acute hospitalized TSCI patients with injuries dated from January 1, 2012 to December 31, 2016 were investigated. Survey sheets were posted to a total of 33 hospitals that provide orthopedic surgery and/or neurosurgery and that might have treated patients with acute hospitalized TSCI in Akita Prefecture. Almost all TSCI patients are initially treated in these hospitals, so that data from these hospitals may provide almost complete epidemiological data for TSCI in Akita Prefecture. TSCI was defined according to the Centers for Disease Control and Prevention as "an acute traumatic lesion of the neural elements in the spinal canal, resulting in temporary or permanent sensory deficit, motor deficit, or bowel/bladder dysfunction" [9]. Doctors with Japanese board-certified orthopedic surgery or neurosurgery retrospectively reviewed medical records and returned the filled-in questionnaire. TSCI following fragility fractures was included in this study. Non-traumatic SCI, delayed-onset paralysis following osteoporotic vertebral fracture and paralysis following pathological fractures due to spinal tumor were excluded. Patients with Frankel E upon their admission to the hospitals were also excluded from the study. In this study, age, sex, date of injury, name of hospital, level of injury (cervical or thoracic/lumbar), presence of skeletal injury, cause, neurological status, and primary treatment were collected. All cases had a clear history of traumatic injury and underwent physical examination, spine X-rays, and magnetic resonance imaging. Computed tomography was performed if attending doctors decided it necessary to confirm skeletal injury. Causes of TSCI were categorized according to a previous study [8]: fall on level surface; fall from <3 m (low fall); fall downstairs; fall from more than 3 m (high fall); struck by object; road traffic accident (RTA); sports; or other. The neurological status on admission was evaluated using Frankel grade according to previous studies in Japan [7, 8, 10]. In addition, because Akita Prefecture also has much snow in winter, snow-related injuries such as RTA, fall from a roof, and winter sports may increase the incidence of TSCI. Thus, the mean seasonal incidence was compared using Kruskal-Wallis one-way analysis of variance. Then the age, gender, presence of skeletal injury, cause, neurological deficits, and seasonal differences were analyzed separately in the cervical injuries and in the thoracolumbar injuries. Continuous variables were compared using Mann-Whitney U test and categorical variables were compared using Fisher's exact test. Statistical analyses were performed using IBM® computer software and SPSS® Statistics version 25.0 for Mac. Values of $p < 0.05$ were considered significant.

Results

Valid responses were obtained from 31 of 33 hospitals (valid response rate 93.9%). The remaining 2 hospitals did not have a spine surgeon and advanced emergency medical service center, so that it could be assumed that TSCI patients were not seen at these hospitals. Thus, almost all acute TSCI patients in Akita Prefecture were included in this study. The mean annual incidence of TSCI excluding Frankel E was 86 per million (range 86–104 per million) with a mean age of 65.9 years and patients in their 60s as the largest age group during the 5-year study period. On average, 75.1% of TSCI patients were male during the present study period, and the male-to-female ratio was 3:1 (Table 1). With regard to the mean extent of TSCI between 2012 and 2016, 53.5% of the patients were classified as

Table 1 Characteristics of the study group

Year	2012	2013	2014	2015	2016
TSCI cases (*n*) (male:female)	111 (88:23)	90 (65:25)	89 (62:27)	72 (55:17)	87 (67:20)
Incidence per million	104	86	86	70	86
Age (years)					
Mean (standard deviation)	63.2 (15.4)	64.8 (14.6)	68.2 (14.4)	68.9 (13.2)	65.3 (17.7)
Median (interquartile range)	63.0 (56.0–73.0)	66.0 (59.0–74.0)	69.0 (62.5–80.0)	68.5 (62.0–79.0)	68.0 (56.0–79.0)
TSCI cases by age (*n*)					
10–19	3	3	1	1	3
20–29	3	0	2	0	2
30–39	0	4	2	0	5
40–49	8	1	3	5	2
50–59	21	15	8	8	12
60–69	36	34	30	23	27
70–79	26	20	20	18	17
80–89	13	11	23	15	16
90–99	1	2	0	2	3
TSCI cases by Frankel grade (*n*)					
A	11	14	15	8	11
B	10	5	5	4	3
C	32	22	28	20	21
D	58	49	41	40	52
Type of injury (*n*)					
Cervical without skeletal injury	82	59	53	43	57
Cervical with skeletal injury	17	21	24	24	23
Thoracic or lumbar injury	12	10	12	5	7

TSCI traumatic spinal cord injury

Frankel D, followed by 27.4% as Frankel C, 13.1% as Frankel A, and 6.0% as Frankel B. Number of TSCI cases by Frankel grade was listed in Table 1. Cervical injury was seen in 89.8%, and cervical TSCI without skeletal injury was seen in 65.5%. The most frequent cause of TSCI was falls on level surfaces (mean 32.1%), followed by falls from <3 m (mean 21.6%) and RTA (mean 15.6%) (Fig. 1). Sports-related injury was the most frequent cause for people in their 10s and 20s. On the other hand, falls on level surfaces increased gradually with advancing age (Fig. 2). In the present study, 78.2% of the acute TSCI patients were treated conservatively as initial treatment. Regardless of the increase in falls off a roof in winter, no significant difference in incidence was found by season ($p = 0.066$).

Of the total sample of patients with a TSCI, 403 were cervical injuries and 46 were thoracolumbar injuries during the 5-year study period (Table 2). The mean age of patients with cervical injuries was significantly higher than that of patients with thoracolumbar injuries (67.0 vs. 62.5, $p = 0.003$). The proportion of skeletal injuries was significantly higher in thoracolumbar injuries than cervical injuries ($p < 0.001$). The proportion of high falls was significantly higher in thoracolumbar injuries than cervical injuries ($p < 0.001$), while the proportion of falls on level surfaces was significantly higher in cervical injuries than thoracolumbar injuries ($p = 0.001$). The proportion of Frankel A was significantly higher in thoracolumbar injuries than cervical injuries ($p = 0.001$), while the proportion of Frankel D was significantly higher in cervical injuries than thoracolumbar injuries ($p = 0.001$). The proportion of conservative treatment was significantly higher in cervical injuries than thoracolumbar injuries to reflect the above results ($p < 0.001$). Seasonal differences were not seen when comparing cervical injuries with thoracolumbar injuries.

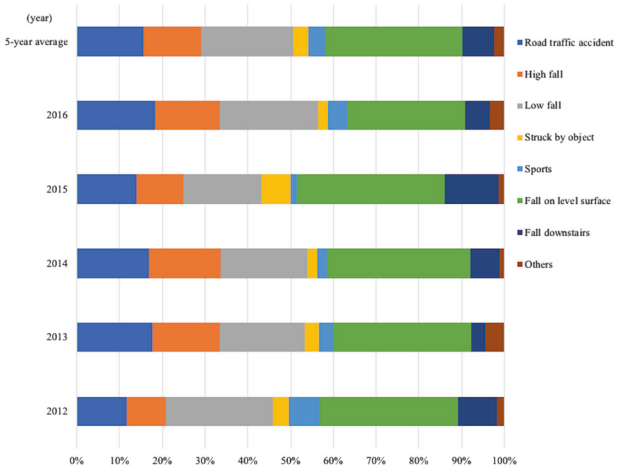

Fig. 1 In the present study, the most frequent cause of traumatic spinal cord injury is falls on level surfaces (mean 32.1%), followed by falls from <3 m (mean 21.6%) and road traffic accident (mean 15.6%)

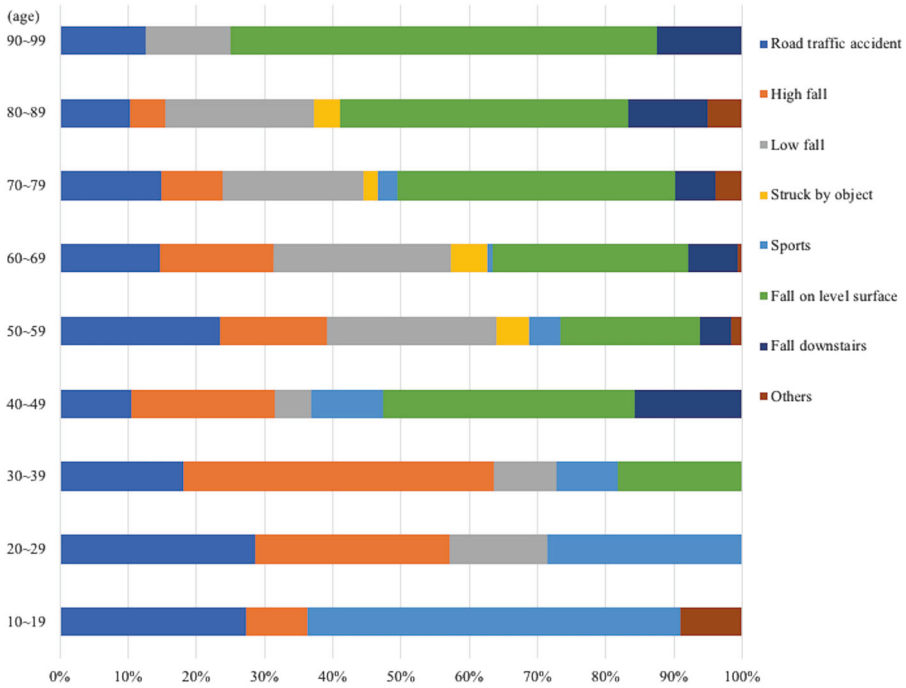

Fig. 2 Sports-related injury is the most frequent cause for people in their 10s and 20s. On the other hand, falls on level surfaces increase gradually with advancing age in the present study

Discussion

With epidemiological information, more appropriate treatment and/or prevention of TSCI may be provided. Japan is the most advanced aging society in the world and a racially homogeneous nation of people with a relatively narrow spinal canal [11]. Indeed, age-related decreases of the anteroposterior diameter of the cervical spinal canal and of disc height on X-ray were shown in asymptomatic volunteers in Japan [12]. In addition, according to the data from Tohoku University, which is located near Akita Prefecture in Japan, the number of spine surgeries increased approximately fivefold during a 25-year period, and 90% of them were performed for degenerative disorders [13]. Because of these facts, cervical SCI due to minor trauma is expected to be increasing in an aging society like Japan. Moreover, Oichi et al. retrospectively investigated 122 consecutive patients with traumatic cervical SCI without bone injury. They concluded that pre-existing severe cervical spinal cord compression was significantly associated with severe paralysis (American Spinal Injury Association Impairment Scale A–C) on multivariate analysis [14]. Therefore, the epidemiological characteristics and changes of TSCI in Akita Prefecture, the fastest aging area in Japan, over a 5-year period were investigated, and the present study could provide a future model for aging societies.

When the proportion of the elderly aged 65 years or older was 15.6% in Akita Prefecture approximately 30 years ago, a similar retrospective epidemiological study was conducted in the same area [10]. Acute hospitalized TSCI patients with injuries dated from January 1, 1989 to December 31, 1990 were retrospectively investigated. Survey sheets were posted to all 19 hospitals that might have treated patients with acute hospitalized TSCI in Akita Prefecture, and the valid response rate was 100%. The mean estimated incidence rate of TSCI, including Frankel E, from 1989 to 1990 in Akita Prefecture was 57 per million, and that excluding Frankel E was 43 per million. The mean ages of TSCI patients including Frankel E in 1989 and 1990 were 54.4 and 52.3 years, respectively. Frankel C was the most frequent (32%), followed by grade D (23%), and RTA was the most frequent cause of TSCI (52.5%), followed by falls from heights (22%) and falls on a level surfaces (15.8%) according to the previous study including Frankel E [10]. The percentage of the population aged 65 years old or older, incidence of TSCI, and falls on level surfaces as a cause of TSCI were double those of approximately 30 years ago. Unfortunately, we could not provide any statistical comparison with the previous study because the raw data of the previous study was not available. However, the epidemiological characteristics have obviously changed.

As expected, the overall incidence of TSCI and the proportion of minor trauma, especially fall-related injuries in the elderly and incomplete spinal cord injuries, have increased in our community. Conversely, the proportion of cases of TSCI due to RTA has decreased. These trends are similar to previous studies in other developed countries, as well as other areas of Japan [8, 15, 16]. In fact, according to a large study in the United States, the percentage of spinal cord injuries due to falls increased significantly from 28% (95% confidence interval (CI), 26–30%) in 1997–2000 to 66% (95% CI, 64–68%) in 2010–2012 in those aged

Table 2 A comparison between cervical injuries and thoracolumbar injuries

Variable	Cervical injuries	Thoracolumbar injuries	*p* Value
Number of cases	403	46	
Age (years)	67.0 (60.0–77.0)	62.5 (56.0–69.0)	0.003
Male:female (*n*)	306:97	31:15	0.211
With skeletal injury (*n*)	109	45	<0.001
Without skeletal injury (*n*)	294	1	
Cause			
Road traffic accident (*n*)	65	5	0.519
High fall (*n*)	38	22	<0.001
Low fall (*n*)	89	8	0.572
Struck by object (*n*)	12	4	0.070
Sports (*n*)	17	1	1.000
Fall on level surface (*n*)	139	5	0.001
Fall downstairs (*n*)	32	1	0.232
Others (*n*)	11	0	0.613
Frankel grade			
A (*n*)	45	14	0.001
B (*n*)	22	5	0.179
C (*n*)	110	13	0.863
D (*n*)	226	14	0.001
Primary treatment			
Surgery (*n*)	67	31	<0.001
Conservative treatment (*n*)	336	15	
Season of injury			
Spring (March–May) (*n*)	83	7	0.444
Summer (June–August) (*n*)	99	10	0.856
Autumn (September–November) (*n*)	103	13	0.723
Winter (December–February) (*n*)	118	16	0.497

Data are expressed as medians (interquartile range)

Continuous variables were compared using Mann-Whitney *U* test and categorical variables were compared using Fisher's exact test

65 years or older ($p < 0.001$). The incidence in men aged 65–74 years also increased from 84 cases per million in 1993 to 131 cases per million [15]. The present study also showed that the most frequent cause of TSCI was falls on level surfaces (mean 32.1%), and falls on level surfaces increased gradually with advancing age.

According to previous studies in the elderly, the incidence of a fall in the past year has been reported to be approximately 30% [17–20]. For the above epidemiological characteristics, prevention of falls in the elderly is needed. First, exercise is considered as an intervention to prevent falls [21]. Second, whether prophylactic decompression surgery for patients with asymptomatic or mildly symptomatic cervical stenosis reduces TSCI is one of the concerns. Indeed, the relative risk of traumatic cervical SCI with cervical spinal canal stenosis (CSCS) was 124.5 times higher than without CSCS [22]. However, only 0.017% of participants with CSCS were estimated to avoid developing traumatic cervical SCI if they underwent decompression surgery before trauma. Takao et al. concluded that prophylactic surgery for CSCS might not significantly affect the incidence of traumatic cervical SCI [22]. Wu et al. also concluded that only 0.3% of cervical spondylotic myelopathy patients can avoid cervical SCI if they undergo surgery before trauma [23]. Chang et al. investigated the risk of SCI after minor trauma in a cohort of prospectively followed cervical stenosis patients. However, no SCI patients were observed in the relatively small number ($n = 55$) of patients [24]. These results suggest that the evidence of usefulness of prophylactic decompression surgery for patients with asymptomatic or mildly symptomatic cervical stenosis to prevent TSCI is still inadequate.

The present study has some limitations. First, falls from a height were distinguished from falls on level surfaces in the present study. While difficulty in distinguishing these causes of TSCI exists in some of the literature, there is no doubt that there is an increase in acute TSCI due to falls on level surfaces or similar low-energy trauma in aging societies.

Second, this study did not include acute TSCI patients who were treated on an outpatient basis. However, almost all acute TSCI patients seem to receive inpatient treatment. In order to increase the response rate, survey items were simplified, and only inpatients were included. Third, we could not provide any statistical comparison with the previous study in Akita Prefecture, because the raw data of the previous study were not available. However, the incidence and main cause of TSCI have obviously changed in approximately 30 years.

In conclusion, recent epidemiological characteristics and changes of TSCI in the fastest aging society in Japan with over 30.0% of the population aged 65 years or older were investigated. The mean annual incidence of TSCI excluding Frankel E was 86 per million with a mean age of 65.9 years and patients in their 60s as the largest age group during the 5-year study period. The estimated incidence rates of TSCI increased approximately twofold compared with about 30 years ago in our community. Over the 2012–2016 period, the most frequent cause of TSCI was falls on level surfaces (mean 32.1%), 53.5% of the patients were classified as Frankel grade D, and 89.8% of the cases involved cervical injury. These trends were similar to those in recent studies in other developed countries.

Disclaimer

This article does not contain any studies with human participants or animals performed by any of the authors.

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Author contributions DK, NM, and YK collected and analyzed the data, prepared and revised manuscript content. YI and NI were responsible for introduction, research method, and result sections. MH and YS were responsible for discussion and conclusion sections.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics approval This study was approved by the Ethics Review Board of Akita University Graduate School of Medicine.

Informed consent Informed consent was obtained from all of the patients in the present study.

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