

Incidence and pattern of traumatic spinal fractures and associated spinal cord injury resulting from motor vehicle collisions in China over 11 years

An observational study

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Abstract

To investigate the incidence and pattern of traumatic spinal fractures (TSFs) and associated spinal cord injury (SCI) resulting from motor vehicle collisions (MVCs).

This was a cross-sectional study. We retrospectively reviewed 698 patients with TSFs resulting from MVCs admitted to our university-affiliated hospitals from 2001 to 2011. The incidence and pattern were summarized with respect to different age groups, fracture levels, and the role of patients.

There were 464 males (66.5%) and 234 females (33.5%) aged 40.5 ± 13.8 years old. The most common roles of patients in MVCs were car drivers (189, 27.1%), pedestrians hurt by a car (155, 22.2%), and car passengers (145, 20.8%). The most common fracture levels were L1 ($n = 198$, 19.2%) and T12 ($n = 116$, 11.3%), followed by C2 ($n = 86$, 8.3%). A total of 298 (42.7%) patients suffered a spinal cord injury. The frequencies of SCIs decreased from 53.1% to 24.6% with increasing age. The patients in the 20 to 39 age group (45.3% of all patients) had the largest sex ratio (2.4) and highest frequency of complete SCIs (19.3%) and complications (3.2%). Motorcycle drivers had the youngest mean age (35.7 ± 10.2), largest sex ratio (10.4), and highest frequency of SCIs (56.0%) and complications (4.4%). Motorcycle passengers had the highest frequency of complete SCI (22.7%) and ASOIs (45.5%) and the largest mean injury severity scoring (ISS) (18.9 ± 9.6). The most common fracture levels of motorcycle drivers were C3–C7, while that of others were T11–L2.

The most common role of patients who sustained TSFs were car drivers who were 20 to 39 years old. Motorcycle drivers had the highest frequency of SCIs and complications. Motorcycle passengers had the highest frequency of complete SCIs and ASOIs and the largest ISS. Therefore, we should pay more attention to MVC patients, especially car drivers and motorcycle drivers and passengers.

Abbreviations: ASOIs = associated injuries, CT = computed tomography, ISS = injury severity scoring, MRI = magnetic resonance imaging, MVCs = motor vehicle collisions, TSCI = traumatic spinal cord injury, TSFs = traumatic spinal fractures.

Keywords: driver, MVCs, passenger, pedestrian, spinal cord injury, spine fracture

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1. Introduction

Traumatic spine and spinal cord injuries are the most common cause of death among young people, and their influence on the social and financial well-being of the patient is often more significant than that of other injuries.^[1–10] Motor vehicle collisions (MVCs) are a common cause of traumatic spinal fractures (TSFs), accounting for between 20.9% and 33.6% of all spinal fractures in different studies.^[8–10] There were many studies about TSFs and especially MVCs, but they also had some limitations, such as single centre data,^[11,12] a small numbers of cases,^[13] and insufficient data to provide accurate information about clinical findings and crash characteristics.^[14,15] MVCs can cause a diversity of injuries in pedestrians and vehicle drivers and passengers. Many factors affect the rate of spinal injuries, such as crash type,^[16,17] vehicle type,^[18] and age.^[19,20] Data recently published by the National Spinal Cord Injury Statistical Centre showed that the most common cause of spinal cord injury (SCI) in the United States between 2010 and 2013 was MVCs (37.9%), followed by falls (29.9%).^[21] Although much is known about SCIs, a comprehensive study of SCIs in MVCs is not available. To our knowledge, no previous studies have evaluated a database that provides comprehensive data on the incidence and pattern of TSFs resulting from MVCs in China especially regarding the

characteristics of spinal fractures according to different roles/positions.

Delays in the diagnosis of spinal fractures and the associated spinal cord injury may result in significantly increased morbidity and mortality. They represent a major focus for traffic injury prevention. In the present study, we reviewed a multicentre (2 tertiary hospitals in Chongqing, China) database of motor vehicle accidents that happened over an 11-year period between 2001 and 2011. The incidence and pattern were summarized with respect to different age groups, fracture levels, and the role of patients.

2. Materials and methods

2.1. Study population

Our study included 698 patients who had acute TSFs that resulted from MVCs between January 2001 and May 2011 and who were admitted to our university-affiliated hospitals. Chongqing Municipality is a city located in southwest China. The data were collected from Third Military Medical University-affiliated hospitals that are the 2 biggest public tertiary hospitals located in the Shapingba district. The Shapingba district is a core district located in the northwest region of Chongqing. We made a definite diagnosis of upper cervical spinal fractures in all patients using X-rays, computed tomography (CT), and magnetic resonance imaging (MRI). The medical records were reviewed and assessed by 2 independent persons who had not participated in treating any patients. The ASIA scoring standard was used to assess spinal cord injury. The study protocol and this manuscript were approved by the committee on ethics and the institutional review board of our institution.

2.2. Statistical analysis

All statistical analyses were performed using SPSS 15.0 (SPSS, Inc., Chicago, IL). Continuous variables were compared between the 2 groups using the Student *t* test, whereas discrete variables were analyzed using the Chi-squared test. The measurement data among different groups were compared with a 1-way analysis of variance. The significance level was set at $P < 0.05$.

3. Results

3.1. Age and gender distribution

The study included 464 males and 234 female patients with a mean age of 40.5 ± 13.8 years old (range 4–88 years old) and a sex ratio of 2.0. The 20 to 39 years old age group accounted for the largest proportion of SCI ($n=316$, 45.3%), followed by the 40 to 59 years old age group ($n=298$, 41.4%). Significant

Age Distribution of All MVC cases

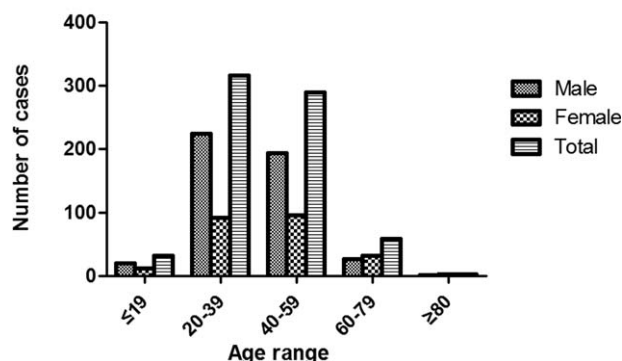


Figure 1. Age distribution of all 698 cases.

differences were observed in the distribution of the sex ratio according to different age groups ($P=0.001$, $t=16.504$). Patients in the 20 to 39 age group had the largest sex ratio of 2.4. The patients in the ≥ 60 age group had the lowest sex ratio of 0.8 (Table 1, Fig. 1). The motorcycle driver patients had a larger sex ratio than the car driver patients ($P=0.003$, $t=8.527$), and the car passenger patients had a larger sex ratio than the motorcycle passenger patients ($P=0.043$, $t=4.095$). The pedestrians injured by a car had a younger mean age ($P=0.047$, $t=-2.006$) and a larger injury severity scoring (ISS) ($P=0.001$, $t=4.177$) than the pedestrians hurt by a motorcycle (Table 2).

3.2. Roles/positions of patients in MVCs

The roles of patients in MVCs, their frequencies, sex ratio, and other characteristics are summarized in Table 2. The most common roles of patients in MVCs were car drivers (189, 27.1%), pedestrians hurt by a car (155, 22.2%), and car passengers (145, 20.8%) (Fig. 2). Motorcycle drivers had the younger mean age (35.7 ± 10.2), largest male-to-female sex ratio (10.4), and the highest frequency of SCI (56.0%) and complications (4.4%). Motorcycle passengers had the highest frequency of completed SCI (22.7%), ASOIs (45.5%), and the largest mean ISS (18.9 ± 9.6).

3.3. Anatomical distribution

The most common fracture level was L1 ($n=198$, 19.2%) and T12 ($n=116$, 11.3%), followed by C2 ($n=86$, 8.3%). The most common fracture levels of motorcycle drivers were C3–C7, while that of others were T11–L2. The 2 most common fracture levels

Table 1

Characteristics of 698 TSFs resulting from MVCs according to different age range groups.

Age range, y	Total	Male/female	SCI, %	Completed/incompleted SCI, %	ASIs, %	Complications, %	MLNSF, %	ISS
≤19	32 (4.6)	20/12 (1.7)	17 (53.1)	4 (12.5)/13 (40.6)	12 (37.5)	1 (3.1)	0	17.5±8.7
20–39	316 (45.3)	224/92 (2.4)	150 (47.5)	61 (19.3)/89 (28.2)	112 (35.4)	10 (3.2)	14 (4.4)	17.0±9.2
40–59	289 (41.4)	193/96 (2.0)	116 (40.1)	39 (13.5)/77 (26.6)	120 (41.5)	7 (2.4)	19 (6.6)	17.0±9.5
≥60	61 (8.7)	27/34 (0.8)	15 (24.6)	0/15 (24.6)	24 (39.3)	0	1 (1.6)	13.5±6.0
<i>P, t</i>	—	0.001, 16.504	0.004, 13.310	0.010, 11.288	0.495, 2.393	0.301, 3.655	0.078, 6.802	—
Total	698 (100)	464/234 (2.0)	298 (42.7)	104 (14.9)/194 (27.8)	268 (38.4)	18 (2.6)	34 (4.9)	16.7±9.1

ISS=injury severity scoring, MLNSF= multiple level noncontiguous spinal fractures, SCI=spinal cord injury.

Table 2**Characteristics of 698 TSFs resulting from MVCs according to different roles.**

Role	Total	Male/female	Mean age, y	SCI, %	Completed/incompleted SCI, %	ASIs, %	Complications, %	MLNSF, %	ISS
Drivers									
Car	189	145/44 (3.3)	37.0±9.0	94 (49.7)	38 (20.1)/56 (29.7)	66 (34.9)	4 (2.1)	14 (7.4)	16.7±8.5
Motorcycle	91	83/8 (10.4)	35.7±10.2	51 (56.0)	18 (19.8)/33 (36.3)	35 (38.5)	4 (4.4)	3 (3.3)	17.9±9.7
<i>P, t</i>	—	0.003, 8.527	0.320, 0.998	0.322, 0.979	0.545, 0.367	0.563, 0.334	0.491, 0.475	0.177, 1.820	0.269, -1.108
Total	280	228/52 (4.4)	36.6±9.3	145 (51.7)	56 (20.0)/89 (31.8)	101 (36.1)	8 (2.9)	17 (6.1)	17.1±8.9
Passengers									
Car	145	98/47 (2.1)	40.5±11.6	53 (36.6)	18 (12.4)/35 (24.1)	47 (32.4)	5 (3.4)	9 (6.2)	15.5±7.6
Motorcycle	22	10/12 (0.8)	36.4±14.7	12 (54.5)	5 (22.7)/7 (31.8)	10 (45.5)	0	0	18.9±9.6
<i>P, t</i>	—	0.043, 4.095	0.141, 1.480	0.107, 2.602	0.865, 0.029	0.229, 1.445	0.831, 0.045	0.487, 0.483	0.124, -1.591
Total	167	108/59 (1.8)	39.9±12.0	65 (38.9)	23 (13.8)/42 (25.1)	57 (34.1)	5 (3.0)	9 (5.4)	17.2±8.9
Pedestrian									
Car	155	77/78 (1.0)	45.8±16.2	49 (31.6)	14 (9.0)/35 (22.6)	68 (43.9)	3 (1.9)	6 (3.9)	16.9±10.1
Motorcycle	10	2/8 (0.3)	56.5±18.5	3 (30.0)	0/3 (30.0)	2 (20.0)	0	0	10.8±3.8
<i>P, t</i>	—	0.135, 2.233	0.047, -2.006	1.000, 0.000	0.680, 0.170	0.250, 1.323	1.000, 0.000	1.000, 0.000	0.001, 4.177
Total	165	79/86 (0.9)	46.5±16.5	52 (31.5)	14 (8.5)/38 (23.0)	70 (42.4)	3 (1.8)	6 (3.6)	16.5±9.9
Others	86	49/37 (1.3)	43.2±13.8	36 (41.9)	11 (12.8)/25 (29.1)	40 (46.5)	2 (2.3)	2 (2.3)	17.4±10.0
Total	698	464/234 (2.0)	40.5±13.8	298 (42.7)	104 (14.9)/194 (27.8)	268 (38.4)	18 (2.6)	34 (4.9)	16.7±9.1

ISS=injury severity scoring, MLNSF= multiple level noncontiguous spinal fractures, MVCs= motor vehicle collisions, SCI= spinal cord injury, TSFs= traumatic spinal fractures.

were T11–L2 ($n=114$, 39.7%) and C3–C7 ($n=71$, 24.7%) in car drivers, C3–C7 ($n=48$, 33.8%) and T11–L2 ($n=30$, 21.1%) in motorcycle drivers, and T11–L2 ($n=92$, 43.0%) and C3–C7 ($n=50$, 23.4%) in car passengers. The 2 most common fracture levels were T11–L2 ($n=12$, 35.3%) and T1–T10 ($n=10$, 29.4%) in motorcycle passengers and both T11–L2 ($n=8$, 57.1%) and T1–T10 ($n=3$, 21.4%) in pedestrians who were hurt by motorcycles. The 2 most common fracture levels were T11–L2 ($n=121$, 57.6%) and L3–L5 ($n=34$, 16.2%) in pedestrians who were hurt by a car (Table 3, Fig. 3).

3.4. Neurological status, associated injuries, complications, and MLNSF

A total of 298 (42.7%) patients suffered a spinal cord injury. Two hundred sixty-eight patients (38.4%) sustained a total of 353 associated injuries (ASOIs), including a thoracic injury in 119

(44.4%) patients, a head and neck injury in 67 (25.0%) patients, an abdomen injury in 5 (1.9%) patients, a pelvic injury in 23 (8.6%) patients, a fracture of an upper extremity in 37 (13.8%) patients, and a fracture of a lower extremity in 42 (15.7%) patients. Eighteen patients sustained a total of 21 complications, such as a pulmonary infection in 11 patients, a bedsore in 6 patients, a deep venous thrombosis in 3 patients, and a postoperative infection in 1 patient. Thirty-four patients ($n=34$, 4.9%) presented with MLNSF (multiple level noncontiguous spinal fractures).

Significant differences were observed in the frequencies of SCI according to different age groups ($P=0.004$, $t=13.310$). The frequencies of SCI decreased from 53.1% to 24.6% with increasing age. The patients in the 20 to 39 age group had the highest frequency of complete SCI (19.3%) and complications (3.2%). The patients in the ≤ 19 -year-old age group presented with the highest frequency of SCI (53.1%) and the highest ISS (17.5 ± 8.7). The patients in the 40 to 59 age group presented with the highest frequency of ASOIs (41.5%) and MLNSF (6.6%). The patients in the ≥ 60 age group had the lowest frequency of SCI (24.6%), complications (0), and the lowest of ISS (13.5 ± 6.0).

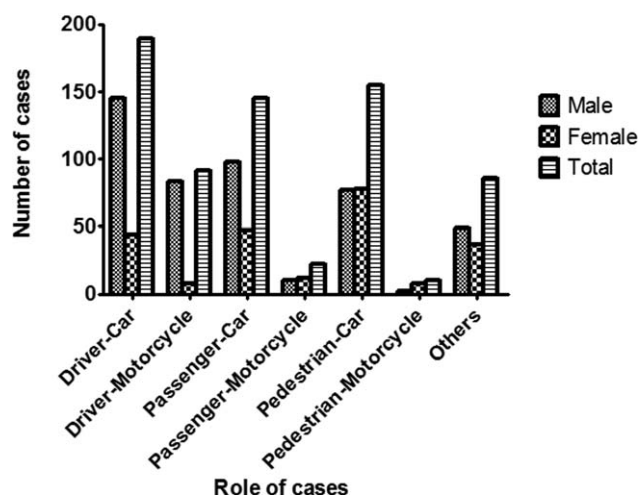
Role Distribution of All MVC cases

Figure 2. Role distribution of all 698 cases.

4. Discussion

In the present study, the most common roles of patients in MVCs were car drivers, pedestrians hurt by a car and car passengers. There were 464 males and 234 female patients with a sex ratio of 2.0 in the study. The results can be explained by the fact that males, such as car or motorcycle drivers, are more involved in daily activities. The 20- to 39-year-old age group accounted for the largest proportion and had the largest male-to-female sex. The most common fracture levels were T11–L2 in car drivers, car passengers, motorcycle passengers, and pedestrians hurt by a motorcycle and car, but C3–C7 in motorcycle drivers. Previous studies have shown that patients in different subgroups of traffic accidents had a diverse distribution of injury subtypes and that the results are directly related to the population studied and the local traffic situation, including transportation devices and traffic regulations. Hill et al^[22] reported that advanced life support measures are appropriate at the scene to stabilize the airway and

Table 3**Fracture level distribution of 698 TSFs resulting from MVCs according to different roles.**

Role	C1–C2	C3–C7	T1–T10	T11–L2	L3–L5	S	Total
Drivers							
Car	37 (12.9)	71 (24.7)	45 (15.7)	114 (39.7)	18 (6.3)	2 (0.7)	287 (27.8)
Motorcycle	23 (16.2)	48 (33.8)	25 (17.6)	30 (21.1)	13 (9.2)	3 (2.1)	142 (13.8)
<i>P, t</i>			0.006, 16.284				—
Total	60 (14.0)	119 (27.7)	70 (16.3)	144 (33.6)	31 (7.2)	5 (1.2)	429 (41.6)
Passengers							
Car	27 (12.6)	50 (23.4)	23 (10.7)	92 (43.0)	20 (9.3)	2 (0.9)	214 (20.8)
Motorcycle	0	6 (17.6)	10 (29.4)	12 (35.3)	4 (11.8)	2 (5.9)	34 (3.3)
<i>P, t</i>			0.003, 18.051				—
Total	27 (10.9)	56 (22.6)	33 (13.3)	104 (41.9)	24 (9.7)	4 (1.6)	248 (24.1)
Pedestrian							
Car	11 (5.2)	10 (4.8)	28 (13.3)	121 (57.6)	34 (16.2)	6 (2.9)	210 (20.4)
Motorcycle	1 (7.1)	0	3 (21.4)	8 (57.1)	2 (14.3)	0	14 (1.4)
<i>P, t</i>			0.744, 2.715				—
Total	12 (5.4)	10 (4.5)	31 (13.8)	129 (57.6)	36 (16.1)	6 (2.7)	224 (21.7)
Others	9 (6.9)	17 (13.1)	26 (20.0)	63 (48.5)	11 (8.5)	4 (3.1)	130 (12.6)
Total	108 (10.5)	202 (19.6)	160 (15.5)	440 (42.7)	102 (9.9)	19 (1.8)	1031 (100)

MVCs = motor vehicle collisions, TSFs = traumatic spinal fractures.

to protect the entire spine of pedestrians with multiple injuries because of the high frequency of brain and vertebral trauma. Thus, we should pay more attention to the prevention and treatment of SCIs in MVCs involving cars among those between 20 and 39 years old, especially C3–C7 fractures in motorcycle drivers and T11–L2 fractures in patients involved with other type of MVCs.

In our study population, the frequencies of spinal cord injury and ASOIs were 42.7% and 38.4%, respectively. The frequencies of SCI decreased from 53.1% to 24.6% with increasing age. The patients in the 20 to 39 age group had the highest frequency of complete SCIs (19.3%). The patients in the ≤ 19 age group presented with the highest frequency of SCIs (53.1%) and the largest ISS. Thus, we should pay more attention to young patients, especially regarding spinal cord injury. The most frequent ASOIs were thoracic injury, followed by head and neck injuries. We should pay more attention to patients who had thoracic vertebral fractures to minimize further complications and mortality.^[23] Car occupants had fewer extremity injuries due to the protective nature of the car cage.^[24] In previous studies, it has been shown that pedestrians are prone to head injuries due to multiple impacts.^[25,26] However, in our study, motorcycle

drivers had the youngest mean age, largest male-to-female sex ratio, and the highest frequencies of SCIs and complications. Motorcycle passengers had the highest frequency of complete SCIs and ASOIs and the largest mean ISS. In many developing urban cities, the increasing rate of MVCs results from economic growth and increasing use of motor vehicles. In Chongqing, which is a mountainous city, the use of motor vehicles is rapidly increasing. Because of a lack of strict traffic safety regulations in China, the probability of sustaining a serious trauma in a vehicle collision is high. We should pay more attention to these injuries and inform younger patients of these injuries, especially those resulting from MVCs involving motorcycles to prevent nerve injuries, respiratory dysfunctions, or death. As is the case in many other countries undergoing similar development, traffic safety regulations need to be adopted.^[27,28]

Eighteen patients (2.6%) sustained complications, such as a pulmonary infection in 11 patients, a bedsore in 6 patients, a deep venous thrombosis in 3 patients, and a postoperative infection in 1 patient; therefore, we should pay more attention to pulmonary infections and bedsores, which were the 2 most common complications. We should pay more attention to pulmonary infections, bedsores, and deep venous thromboses especially among patients aged 40 to 59 years old. Thirty-four patients had MLNSF. The patients in the 40 to 59 age group had the highest frequency of MLNSF. Car drivers and car passengers had a greater frequency of MLNSF than did motorcycle occupants. Previous studies noted that MVCs were the primary cause of multiple noncontiguous spine fractures. The failure to use seat belts and ejection from the vehicle were the main factors associated with multiple noncontiguous spine injuries.^[29] Multiple noncontiguous injuries had a more complicated mechanism of injury and tended to be more severe injuries than single-level injuries as they were combined more frequently with injuries of other parts of the body.^[30,31] Multilevel spine injuries are most common in children between 9 and 16 years of age and are mainly located in the cervical region.^[32] Although multiple level noncontiguous fractures of the spine are uncommon, they constitute a threat to neurologic function and therefore warrant radiographic evaluation of the entire spine with multiple injuries.^[33] Imaging studies that evaluate patients with spinal injuries should include at least three levels above and below the

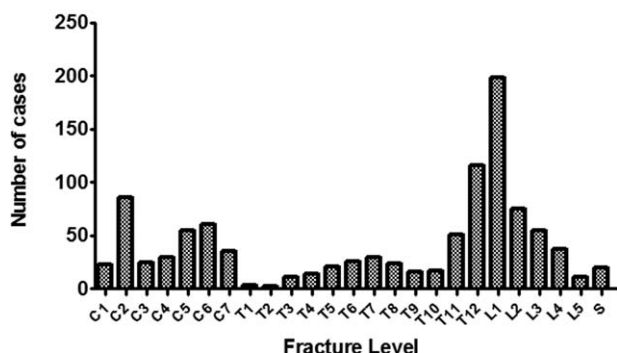
Fracture Level Distribution of All MVC cases

Figure 3. Fracture level distribution of all 698 cases.

primary level of injury in addition to the entire thoracic spine and thoracolumbar junction.^[34] We should pay more attention to car drivers and passengers, especially if MLNSF are found among them to avoid a missed diagnosis. This study has several limitations. First, it was limited by the retrospective study design and the small number of patients. Second, there may be selection bias because this study includes patients referred to our teaching hospitals.

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