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Traumatic upper cervical spinal fractures in teaching hospitals of China over 13 years

A retrospective observational study

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Abstract

To investigate the incidence and pattern of patients managed for traumatic upper cervical spinal fractures (TUCSFs) in teaching hospitals in China over 13 years.

We retrospectively reviewed 351 patients with TUCSF admitted to our teaching hospitals. Incidence rates were calculated with respect to age, gender, etiologies of trauma, anatomical distribution, anatomical classification, American spinal injury association impairment scale (ASIA) classification of neurological deficit and associated injuries.

There were 260 male and 91 female patients, with a mean age of 44.2 ± 16.3 years. The mean age of the patients significantly increased by year of admission, from 35.2 ± 14.5 years to 47.5 ± 17.2 years ($P = 0.005$). Motor vehicle accidents (MVAs) (n = 132, 37.6%) and high falls (n = 104, 29.6%) were the 2 most common mechanisms. The number of C2 fractures (n = 300, 85.5%) was significantly higher than that of C1 (n = 99, 28.2%) ($P < 0.001$). High falls resulted in significantly more Type I C1 fractures than other etiologies (all $P < 0.001$). MVAs resulted in many more Type II and Type III C1 fractures and Type II and Type III C2 fractures than other etiologies. High falls were the most common injury type (n = 44, 36.4%) resulting in neurological deficits. Patients who presented with Landell classification Type I single C1 fracture (n = 6, 42.9%) had the highest rate of neurological deficits. Eighty-two patients had combined injuries; the most common pattern was cervical + cervical spine (n = 44, 12.5%), followed by cervical + thoracic spine (n = 27, 7.7%). A total of 121 patients (34.5%) suffered neurological deficits. Of all patients with TUCSF without combined injuries, single C2 fractures accounted for the highest rate of neurological deficits (n = 62, 32.0%). Multivariate logistic regression analysis indicated that sex (OR = 1.876, 95% CI: 1.022–3.443, $P = 0.042$), etiology (MVA pedestrians vs high fall: OR = 0.187, 95% CI: 0.056–0.629, $P = 0.007$), level (C1 + OFs vs C1: OR = 6.264, 95% CI: 1.152–34.045, $P = 0.034$), and injury severity scoring (ISS) (OR = 1.186, 95% CI: 1.133–1.242, $P < 0.001$) were independent risk factors of neurological deficit.

The most common causes of TUCSF were MVAs and high falls; single C2 fractures without combined injuries accounted for the most common neurological deficits. Different etiologies resulted in different specific anatomical injuries and neurological deficits. We should make early diagnoses and initiate timely treatment according to different TUCSF patterns.

Abbreviations: ASOIs = associated injuries, CT = computed tomography, ISS = injury severity scoring, MRI = magnetic resonance imaging, MVAs = motor vehicle accidents, OFs = other fracture levels, TCSFs = traumatic cervical spinal fractures, TSFs = traumatic spinal fractures, TUCSFs = traumatic upper cervical spinal fractures.

Keywords: cervical, epidemiology, fracture, neurological deficits, spine

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1. Introduction

Traumatic spinal fractures (TSFs), and traumatic cervical spinal fractures (TCSFs) in particular, are major causes of disability and death; family members of patients can experience shock and sadness, and these fractures can place a heavy burden on patients' family and society.[1–10] In recent years, only a few studies on the epidemiological characteristics of TSFs and TCSFs have been published.[1–10] The annual incidence of TCSF in the general Norwegian population was reported to be 15.0/100,000.[7] In China, the mean annual incidence of TCSF was 65 cases per 100,000 hospital admissions.[10] To the best of our knowledge, there are few studies discussing the incidence and pattern of traumatic upper cervical spinal fractures (TUCSFs), meaning fracture of the atlas and axis.[11,12] Compared with younger patients with cervical spinal fractures, elderly patients have a greater proportion of upper cervical spinal fractures.[13,14] Falls were the most common trauma mechanism resulting in TCSF, and SCI was observed in 10%.[7] Combined injuries following TCSF are frequently encountered, and their distribution characteristics are well investigated; however, there were no studies on the age and gender distribution, etiologies, anatomical distribution and classifications, neurological deficits, associated injuries (ASOIs), and combined injuries among TUCSF patients.[5–7,10] Overlooking the incidence and pattern may lead to inappropriate and delayed management.

Upper cervical spine injuries with severe neurological deficit commonly result in death. In those who survive, upper cervical spine injury is occasionally overlooked due to the lack of characteristic clinical symptoms and sometimes mild or absent neurological deficits. It is very important to evaluate patients presenting with TUCSF in order to diagnose the injury and initiate the appropriate therapeutic measures at an early stage. In the present study, we investigated the incidence and pattern of patients managed for TUCSF in our teaching hospitals in China over 13 years. The incidence rate ratios were then calculated with respect to age, gender, etiology of trauma, anatomical distribution, anatomical classification, ASIA classification of neurological deficit, and ASOIs.

2. Methods

2.1. Study population

This study was a retrospective cross-sectional study. Our study included 351 patients who presented with TUCSF between January 2001 and May 2013 and were admitted to our university affiliated hospitals. The types of spinal fracture and etiologies were coded according to the International Classification of Diseases, 9th revision (ICD-9), by professional medical record coding personnel in the medical record coding department of the hospitals. Data were collected from 2 hospitals (Xinqiao Hospital and Southwest Hospital) affiliated with the Third Military Medical University in Chongqing, China, the 2 largest tertiary hospitals in the Shapingba district, which is a core district located in the northwest region of Chongqing city. The study protocol and publication of the study were approved by the committee on ethics and the institutional review board of our institution.

2.2. Data collection

We made definitive diagnoses of TUCSFs in all patients using X-rays, computed tomography (CT), and magnetic resonance imaging (MRI). To control for various biases, the inclusion and exclusion criteria were added, and blinded procedures were used to collect data and control for information bias. The inclusion criteria in this study included all patients admitted to our university-affiliated hospitals who presented with TUCSFs. The exclusion criteria were pathologic or osteoporotic fractures. Medical records were reviewed and assessed by 2 independent persons who did not participate in treating any patients. The mechanisms of trauma included high falls (height $\geq$2 m), low falls (height <2 m), motor vehicle accidents (MVAs), being struck by an object and other. The ASIA scoring standard was used to assess neurological deficits (ASIA A: complete motor and sensory deficit; ASIA B: complete motor deficit with some remaining sensory function; ASIA C: inefficient motor function; ASIA D: useful remaining motor function; ASIA E: normal motor and sensory function). In our study, "combined injuries" meant injuries involving 2 or more different vertebrae, except for both C1 and C2 fractures.

The anatomic classifications of upper cervical spinal fractures were determined using CT images. C1 fractures were classified according to the Landell classification (Type I: fracture of the anterior or posterior arch of the atlas; Type II: fracture of the anterior and posterior arch of the atlas; Type III: fracture of the lateral mass of the atlas). C2 odontoid fractures were classified according to the Anderson classification (Type I: an oblique fracture at the tip of the odontoid process. Type II: a fracture at the neck or base of the odontoid but not extending into the body of the axis. Type III: a fracture extending down into the body of the axis). Incidence rate ratios were then calculated with respect to different age and gender groups, etiology of trauma, anatomical distribution, anatomical classification, ASIA classification of neurological deficit, and ASOIs.

2.3. Statistical analysis

Data are expressed as the mean $\pm$ standard deviation for continuous variables and as the frequency/percent for categorical variables. All statistical analyses were performed using SPSS 15.0 (SPSS, Inc., Chicago, IL). The basic characteristics of the patients were compared using Mann–Whitney *U* test (for continuous variables) or Chi-square test (for categorical variables). The measurement data were compared between the 3 groups with 1-way analysis of variance. Univariate and multiple logistic regression analyses were used to analyze the possible factors associated with neurological deficits after TUCSF. The significance level was set at $P < 0.05$.

3. Results

This study included 256 (72.9%) male and 95 (27.1%) female patients, for a male-to-female ratio of 2.7. The mean age of the patients was 44.2 $\pm$ 16.3 years (range 14–88 years old). The 31- to 40-year-old age group accounted for the largest proportion (n = 80, 22.8%), followed by the 51- to 64-year-old age group (n = 78, 22.2%). The mean age of the patients significantly increased with year of admission, from 35.2 $\pm$ 14.5 years to 47.5 $\pm$ 17.2 years ($P = 0.005$) (Tables 1 and 2, Fig. 1). Accidental falls including high and low falls were the most common mechanism of injury (n = 171, 48.7%), and high falls accounted for 104 (29.6% of all fractures). The second most common mechanism was MVA (n = 132, 37.6%), and most patients in this category were motor vehicle drivers (n = 66, 18.8% of all fractures).

The number of C2 fractures (n = 300, 85.5%) was significantly higher than that of C1 fractures (n = 99, 28.2%) ($P < 0.001$).

Table 1

Characteristics of TUCSF according to admission time from January 2001 to December 2012.

Admission time	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012
Number of cases	19	21	37	64	108	84
Age (mean ± SD)	35.2±14.5	38.9±13.3	43.2±17.6	43.7±11.5	44.5±17.5	47.5±17.2
Gender						
Male/female	15/4 (3.8)	16/6 (2.7)	24/13 (1.8)	51/13 (3.9)	84/24 (3.5)	60/24 (2.5)
Etiology						
High fall	5 (26.3%)	7 (33.3%)	10 (27.0%)	18 (28.1%)	31 (28.7%)	33 (39.3%)
Low fall	4 (21.1%)	5 (23.8%)	6 (16.2%)	7 (10.9%)	28 (25.9%)	15 (17.9%)
MVA	7 (36.8%)	6 (28.6%)	17 (45.9%)	32 (50.0%)	31 (28.7%)	33 (39.3%)
Struck by object	2 (10.5%)	3 (14.3%)	3 (8.1%)	5 (7.8%)	10 (9.3%)	8 (9.5%)
Others	1 (5.3%)	0	1 (2.7%)	2 (3.1%)	8 (7.4%)	2 (2.4%)
Fractured vertebral body						
C1 (+OFs)	4 (21.1%)	4 (19.0%)	4 (10.8%)	14 (21.9%)	12 (11.1%)	11 (13.1%)
C2 (+OFs)	14 (73.7%)	11 (52.4%)	28 (75.7%)	43 (67.1%)	81 (75.0%)	64 (76.2%)
C1 + C2 (+OFs)	1 (5.3%)	6 (28.6%)	5 (13.5%)	7 (10.9%)	15 (13.9%)	9 (10.7%)
ASIA score						
A	0	3 (14.3%)	3 (8.1%)	3 (4.7%)	8 (7.4%)	3 (3.6%)
B	1 (5.3%)	0	1 (2.7%)	3 (4.7%)	1 (0.9%)	1 (1.2%)
C	0	3 (14.3%)	1 (2.7%)	0	2 (1.8%)	5 (6.0%)
D	8 (42.1%)	3 (14.3%)	5 (13.5%)	15 (23.4%)	31 (28.7%)	14 (16.7%)
E	10 (52.6%)	12 (57.1%)	27 (73.0%)	43 (67.2%)	66 (61.1%)	61 (72.6%)
Associated injuries	3 (15.8%)	10 (47.6%)	12 (32.4%)	17 (26.6%)	42 (38.9%)	36 (42.9%)

MVA = motor vehicle accidents, OFs = other fracture levels, TUCSFs = traumatic upper cervical spinal fractures.

Table 2

Characteristics of TUCSF in China according to different fracture level from 2001 to 2013.

	C1	C2	C1 + C2	C1 + OFs	C2 + OFs	C1 + C2 + OFs	Total
Number of cases	39	194	36	12	58	12	351
Age (mean ± SD)	43.4±12.3	41.5±12.3	52.4±15.4	43.8±16.1	47.8±13.6	49.9±16.0	44.2±16.3
Gender							
Male/female	28/11 (2.5)	148/46 (3.2)	27/9 (3.0)	9/3 (3.0)	40/18 (2.2)	8/4 (2.0)	260/91 (2.9)
Etiology							
High fall	14 (35.9%)	42 (21.6%)	16 (44.4%)	7 (58.3%)	23 (39.7%)	2 (16.7%)	104 (29.6%)
Low fall	5 (12.8%)	42 (21.6%)	6 (16.7%)	1 (8.3%)	12 (20.7%)	1 (8.3%)	67 (19.1%)
MVA	16 (41.0%)	85 (43.8%)	10 (27.8%)	4 (33.3%)	13 (22.4%)	4 (33.3%)	132 (37.6%)
Struck by object	4 (10.3%)	13 (6.7%)	4 (11.1%)	0	7 (12.1%)	5 (41.7%)	33 (9.4%)
Others	0	12 (6.2%)	0	0	3 (5.2%)	0	15 (4.3%)
Neurological deficit	9 (23.1%)	62 (32.0%)	8 (22.2%)	7 (58.3%)	30 (51.7%)	6 (50.0%)	121 (34.5%)
Associated injuries	14 (35.9%)	65 (33.5%)	12 (33.3%)	7 (58.3%)	22 (37.9%)	7 (58.3%)	127 (36.2%)
ISS	14.2±6.8	14.2±6.2	13.6±6.1	17.8±10.3	19.8±11.0	20.1±11.0	15.4±7.9

ISS = injury severity scoring, MVA = motor vehicle accidents, OFs = other fracture levels, TUCSFs = traumatic upper cervical spinal fractures.

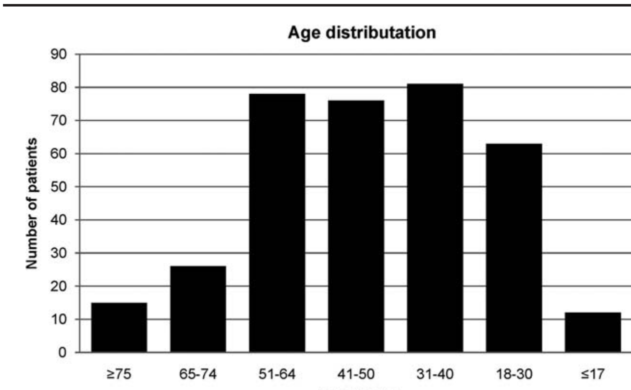

Figure 1. Age distribution of patients presenting with TUCSF.

Most of the patients (n=24, 60.0%) who presented with Type I C1 fractures according to Landell classification had experienced high fall injuries. Most of the patients presenting with Type II (n=13, 41.9%) and Type III (n=14, 50.0%) C1 fractures according to Landell classification had been injured in MVAs. Most of the patients (n=18, 30.0%) presenting with Type I C2 fractures according to Anderson classification had suffered a high fall. Most of the patients who presented with Type II (n=56, 45.2%) and Type III (n=38, 37.6%) C2 fractures according to Anderson classification were injured in MVAs. There were significantly more C2 fractures (n=300, 85.5%) than C1 fractures (n=99, 28.2%). According to Landell classification, Type I C1 fractures were present in 40 (11.4%), Type II C1 fractures in 31 (8.8%), and Type III C1 fractures in 28 patients (8.0%). Type I C1 fractures resulted from high falls significantly more often than from other etiologies ($P < 0.001$). Type II and Type III C1 fractures and Type II and Type III C2 fractures resulted from MVAs more often than from other etiologies

Table 3

Characteristics of C1 according to Landell classification and C2 fracture according to Anderson classification.

Types	C1 fracture—Landell classification			C2 fracture—Anderson classification		
	Type I	Type II	Type III	Type I	Type II	Type III
Cases	40	31	28	75	124	101
Age (mean ± SD)	48.1 ± 14.3	49.9 ± 15.1	44.1 ± 15.0	46.4 ± 18.8	41.3 ± 16.4	46.7 ± 15.2
Gender						
Male/female	31/9 (3.4)	23/8 (2.9)	18/10 (1.8)	54/21 (2.6)	99/25 (4.0)	70/31 (2.3)
Etiology						
High fall	24 (60.0%)	7 (22.6%)	8 (28.6%)	24 (32.0%)	30 (24.2%)	29 (28.7%)
Low fall	4 (10.0%)	7 (22.6%)	2 (7.1%)	18 (24.0%)	26 (21.0%)	17 (16.8%)
MVA	7 (17.5%)	13 (41.9%)	14 (50.0%)	18 (24.0%)	56 (45.2%)	38 (37.6%)
Struck by object	5 (12.5%)	4 (12.9%)	4 (14.3%)	9 (12.0%)	8 (6.5%)	12 (11.9%)
Others	0	0	0	6 (8.0%)	4 (3.2%)	5 (5.0%)
Associated injuries	15 (37.5%)	13 (41.9%)	12 (42.9%)	25 (33.3%)	44 (35.5%)	37 (36.6%)
ISS	17.3 ± 9.7	12.5 ± 5.3	15.0 ± 6.6	15.7 ± 8.8	15.0 ± 7.2	15.8 ± 8.3

ISS = injury severity scoring, MVA = motor vehicle accidents, OFs = other fracture levels.

(Table 3). According to Anderson classification, Type I C2 fractures occurred in 75 (21.4%), Type II C2 fractures in 124 (35.3%), and Type III C2 fractures in 101 patients (28.8%). Patients with Type II C2 fractures had the youngest mean age and the largest sex ratio (Table 3, Fig. 2). Eighty-two (23.4%) patients had suffered combined injuries including cervical + thoracic spine (n = 27, 7.7%), cervical + cervical spine (n = 44, 12.5%), cervical + lumbar spine (n = 9, 2.6%), and cervical + thoracic + lumbar spine (n = 2, 0.6%) (Table 2). In the MVA group, most patients presenting with Type I, Type II, Type III C1 fractures were the driver (n = 4, 57.1%), passenger (n = 7, 53.8%), and driver (n = 7, 50.0%), respectively. Most patients presenting with Type I, Type II, Type III C2 fractures were the driver (n = 12, 66.7%), driver (n = 32, 57.1%), and passenger (n = 15, 39.5%), respectively (Fig. 3).

A total of 121 (34.5%) patients presented with spinal cord injury (SCI). Using the ASIA scoring standard, 20 patients (5.7% of the total study population) exhibited ASIA A deficits, 7 patients

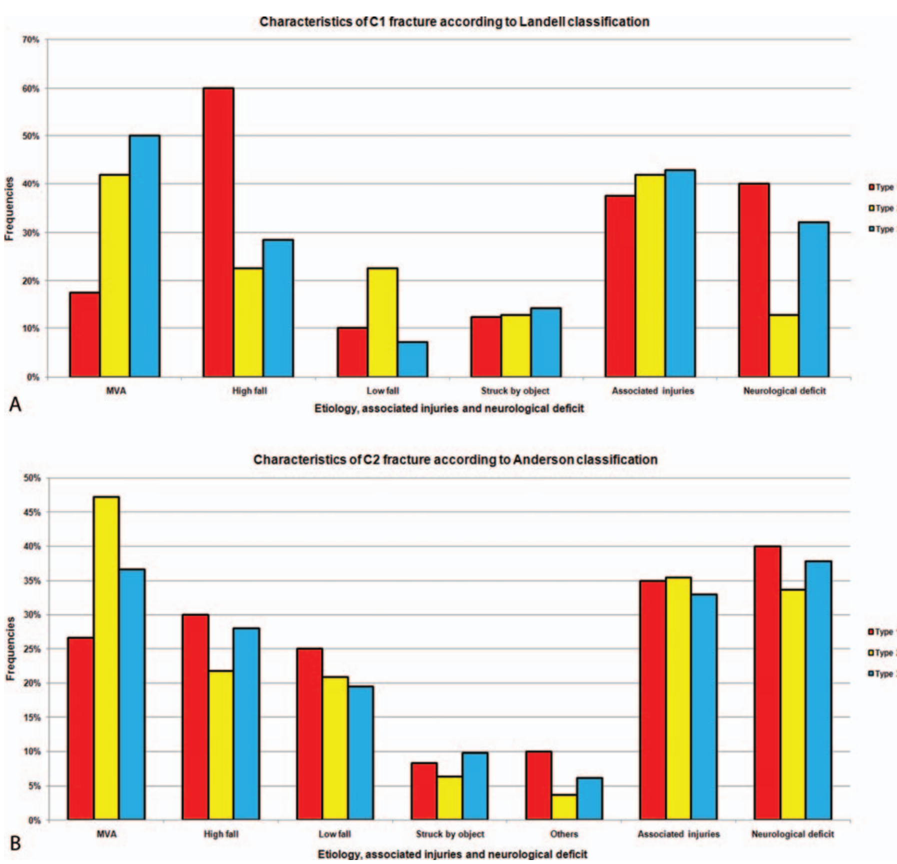

Figure 2. Characteristics of patients presenting with traumatic C1 or C2 spine fracture. (A) Characteristics of C1 fracture according to Landell classification. (B) Characteristics of C2 fracture according to Anderson classification.

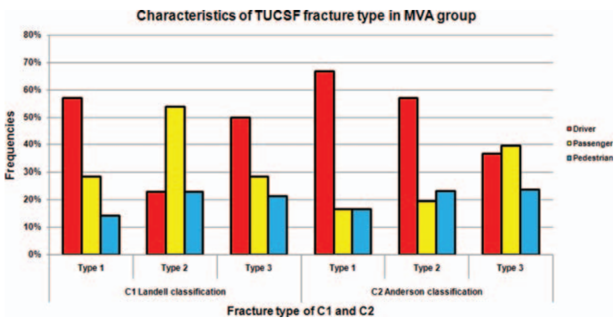

Figure 3. Characteristics of patients presenting with TUCSF in the MVA group.

(2.0%) ASIA B, 13 patients (3.7%) ASIA C, and 81 patients (23.1%) ASIA D. Among all the patients with TUCSF, except for those with combined injuries, single C1 fractures accounted for 39, neurological deficits accounted for 9 (23.1%), single C2 fractures accounted for 194, neurological deficits accounted for 62 (32.0%), and both C1 and C2 fractures accounted for 36, neurological deficits accounted for 8 (22.2%) (Table 4). Among all the patients with TUCSF, except for those with combined injuries, single C2 fractures accounted for the highest rate of neurological deficits (Table 2). Most of the patients who presented with ASIA A neurological deficits were associated with a single C2 fracture (n=14, 70%) (Table 5). Patients presenting with Type I C1 fractures according to Landell classification had the highest rate of neurological deficit (n=16, 40%) among all patients presenting with C1 fractures. Patients with Type I C2 fractures according to Anderson classification had the highest rate of neurological deficit (n=24, 40%) among all patients with C2 fractures. Thirty-eight patients assessed as ASIA Grade D evolved to Grade E. Additionally, 12.5% (44/351) of the patients with an incomplete SCI improved 1 or more than 1 grade in the ASIA scoring standard during their hospitalization; 1 patient evolved from ASIA B to Grade D, 4 patients from ASIA C to Grade D, and 1 patient from ASIA C to Grade E. One hundred twenty-seven patients (36.2%) sustained ASOIs. Head injury occurred in 78 (22.2%) patients, thoracic injury in 41 (11.7%), pelvic injury in 6 (1.7%), fracture of an upper extremity in 24 (6.8%), and fracture of a lower extremity in 18 (5.1%) (Table 5).

We conducted univariate logistic regression analysis and found that sex ($P=0.090$), etiology ($P=0.066$), level ($P=0.009$), and injury severity scoring (ISS) ($P<0.001$) may be risk factors of neurological deficit. Furthermore, the multivariate logistic regression analysis indicated that sex (OR=1.876, 95% CI: 1.022–3.443, $P=0.042$), etiology (MVA pedestrians vs high fall: OR=0.187, 95% CI: 0.056–0.629, $P=0.007$), level (C1+OFs vs C1: OR=6.264, 95% CI: 1.152–34.045, $P=0.034$), and ISS (OR=1.186, 95% CI: 1.133–1.242, $P<0.001$) were independent risk factors of neurological deficit (Table 6).

4. Discussion

MVAs were the most common mechanism of TUCSFs in this study, followed by high falls. These findings are consistent with a study conducted by Clayton et al,[15] who noted that MVAs and falls were independent factors associated with cervical spine injuries. There were 260 male and 91 female patients in this study. The results can be explained by the fact that males may be more involved in daily activities and more frequently hurt. The 31 to 40 years age group accounted for the highest rate of TUCSFs, and we should thus pay close attention to the prevention and

Table 4

Neurological deficit of C1 and/or C2 fracture.

Data	Single C1 fracture				Single C2 fracture				Both C1 and C2
	Type I	Type II	Type III	Total	Type I	Type II	Type III	Total	Total
Number of cases	14	16	9	39	49	92	53	194	36
Neurological deficit (%)	6 (42.9)	2 (12.5)	1 (11.1)	9 (23.1)	17 (34.7)	29 (31.5)	16 (30.2)	62 (32.0)	8 (22.2)

Table 5

Characteristics of TUCSF according to ASIA score.

ASIA score	A	B	C	D	A, B, C, D	E
Number of cases	20	7	13	81	121	230
Age (mean±SD)	43.2±16.8	52.9±18.1	49.6±15.2	43.5±15.7	44.6±16.0	44.0±16.5
Gender						
Male/female	13/7 (1.9)	6/1 (6.0)	8/5 (1.6)	56/25 (2.2)	83/38 (2.2)	177/53 (3.3)
Etiology						
High fall	10 (50.0%)	3 (42.9%)	4 (30.8%)	27 (33.3%)	44 (36.4%)	60 (26.1%)
Low fall	2 (10.0%)	1 (14.3%)	0	16 (19.8%)	19 (15.7%)	48 (20.8%)
MVA	4 (20.0%)	0	6 (46.2%)	25 (30.9%)	35 (28.9%)	97 (42.2%)
Struck by object	4 (20.0%)	2 (28.6%)	3 (23.1%)	8 (9.9%)	17 (14.0%)	16 (7.0%)
Others	0	1 (14.3%)	0	5 (6.2%)	6 (5.0%)	9 (3.9%)
Level						
Single C1	2 (10.0%)	0	1 (7.7%)	6 (7.4%)	9 (7.4%)	30 (13.0%)
Single C2	5 (25.0%)	2 (28.6%)	5 (38.5%)	50 (61.7%)	62 (51.2%)	132 (57.4%)
Both C1+C2	0	1 (14.3%)	4 (30.8%)	3 (3.7%)	8 (6.6%)	28 (12.2%)
Associated injuries	12 (60.0%)	1 (14.3%)	5 (38.5%)	24 (29.6%)	42 (34.7%)	85 (37.0%)
ISS	31.3±9.3	20.9±9.5	20.1±7.7	18.0±4.3	20.5±7.7	12.7±6.6

ISS=injury severity scoring, MVA=motor vehicle accidents, OFs=other fracture levels, TUCSFs=traumatic upper cervical spinal fractures.

Table 6

Univariate and multivariate analysis of risk factors for neurological deficit.

Characteristics	Univariate analysis			Multivariate analysis		
	OR	95% CI	*P*	OR	95% CI	*P*
Sex						
Male vs female	1.529	0.935–2.499	0.090	1.876	1.022–3.443	0.042
Age, y						
≥60 vs 45–59 vs ≤44	0.998	0.749–1.328	0.986			
Etiology			0.066			0.047
Low fall vs high fall	0.540	0.279–1.043	0.066	0.707	0.324–1.542	0.384
Struck by object vs high fall	1.449	0.660–3.179	0.355	1.733	0.681–4.407	0.249
MVA passenger vs high fall	0.524	0.229–1.199	0.126	0.522	0.197–1.385	0.191
MVA pedestrians vs high fall	0.496	0.202–1.217	0.126	0.187	0.056–0.629	0.007
MVA drivers vs high fall	0.473	0.241–0.929	0.030	0.690	0.308–1.545	0.367
Others vs high fall	0.909	0.301–2.741	0.866	1.321	0.389–4.479	0.655
Level			0.009			0.198
C2 vs C1	1.566	0.701–3.497	0.274	2.205	0.840–5.789	0.108
C1 + OFs vs C1	4.667	1.188–18.332	0.027	6.264	1.152–34.045	0.034
C2 + OFs vs C1	3.571	1.444–8.834	0.006	2.305	0.760–6.990	0.140
C1 + C2 vs C1	0.952	0.323–2.812	0.930	1.045	0.298–3.660	0.945
C1 + C2 + OFs vs C1	2.381	0.606–9.353	0.214	1.301	0.249–6.789	0.755
Associated injuries						
Yes vs no	0.907	0.572–1.437	0.677			
ISS	1.167	1.120–1.215	0.000	1.186	1.133–1.242	0.000

CI = confidence interval, ISS = injury severity scoring, MVA = motor vehicle accident, OFs = other fracture levels, OR = odds ratio.

treatment of MVAs and high falls among 31- to 40-year-old people in particular. The most common fractured vertebral body was C2. In the present study, 23.4% of the 351 patients had combined injuries, with cervical + cervical spine (12.5%) and cervical + thoracic spine (7.7%) representing the most common types. A total of 1.7% of the patients with lower cervical spine injuries had sustained a combined injury in the upper cervical spine in a previous study.[12] In our study, a total of 12.5% of the patients with upper cervical spinal fracture had sustained a combined injury in the lower cervical spinal fracture.

The neurological deficits in patients presenting with TUCSF can be absent or mild. This occurs because the sagittal diameter of the upper cervical spinal canal is wider than that of the lower cervical spine and the spinal cord can move up and down according to the movement of the cervical spine.[16,17] This should allow the upper cervical spinal cord to resist injury to some extent. Neurological deficits, although mild, may be a consequence of an unstable injury that could result in death if left unattended.[18] Therefore, it is necessary to have sufficient knowledge of the characteristic neurological deficits associated with upper cervical spine injury according to the etiologies and anatomical classifications. In the present study, Type I C1 fractures resulted from high falls significantly more often than from other etiologies. Type II and Type III C1 fractures and Type II and Type III C2 fractures resulted from MVAs more than from other etiologies. Patients presenting with Landell classification Type I C1 fractures had the highest rate of neurological deficits. Accordingly, we should pay close attention to patients injured by high falls and those who present with Landell classification Type I C1 fractures.

In our study population, the presence of neurological deficits and ASOIs was 34.5% and 36.2%, respectively. Among all patients with TUCSF, except for those with combined injuries, single C2 fractures accounted for the highest rate of neurological deficits. A previous study showed that the incidence of neurological deficits in upper cervical spine injury was 33%, which was consistent with our study.[19] The most frequently observed ASOIs were head injuries, followed by thoracic injuries. We should pay close attention to these injuries and protect these patients from aggravating nervous injuries, respiratory dysfunction, or death.[20–22] Because CT examinations of the cervical spine were not performed at the time of injury in some patients, the diagnosis of cervical spinal fracture was delayed, and more operations were necessary.[23] Imura et al[23] noted that surgeons should consider the possibility of cervical fractures, especially in patients who are comatose at injury to avoid unnecessary surgical treatment. Our data are consistent with the findings that combined injuries and ASOIs in TUCSF are common. If fractures are suspected, additional radiographs, especially CT scans or MRIs, should be conducted as soon as possible after the injury to ensure that the diagnoses and appropriate therapeutic measures are determined at an early stage.

Surgical treatment was performed in 211 patients (60.1%), and anterior or posterior minimally invasive surgery (APMIS) was performed in 36 patients (10.3%). The surgical technique of microendoscopic anterior release, reduction, fixation, and fusion is a safe and reliable minimally invasive option for treating traumatic upper cervical injuries and has several potential advantages including less tissue trauma and better accuracy.[24,25] Iso-C3D-based image-guided percutaneous cervical screw placement has been shown to be a feasible minimally invasive treatment option for uncomplicated cervical fractures.[26] The integration of minimally invasive surgical techniques and intraoperative 3D navigation has been proven to be feasible and safe for treating Hangman fracture, with significantly reduced iatrogenic soft tissue injury.[27] Computer navigation can also increase the accuracy of dorsal lateral mass screw fixation in spinal trauma.[28] With the development of minimally invasive spine surgeries including advanced surgical instruments and intraoperative navigation systems, TUCSFs can be treated with reduced morbidity, blood loss, and length of hospital stay.

This study has several limitations. First, the retrospective study design and the small number of patients are limitations. Second, our results did not provide the in-hospital mortality rate because 35 (10.0%) patients stopped receiving treatment and left the hospital within 5 days. This can be explained by financial reasons. In developing countries such as China, the government manages most of the medical insurance. Most low-income people such as laborers and peasants have to pay the high medical costs at their own expense because of the low rates of medical insurance coverage; accordingly, they terminated their treatment.[9,10,29] Therefore, we were unable to measure the in-hospital mortality rate. Third, there may be a selection bias because this study included patients referred to our teaching hospitals.

5. Conclusions

The most common causes of TUCSF were MVAs and high falls; single C2 fractures, excluding combined injuries, accounted for the most common neurological deficits. Combined injuries represented a high proportion, especially cervical + cervical spine injuries. Different etiologies resulted in different specific anatomical classification of fractures and different rates of accompanying neurological deficits. High falls resulted in significantly more Type I C1 fractures than other etiologies. Patients presenting with Landell classification Type I C1 fractures had the highest rate of neurological deficits. We should strive to make early diagnoses and provide timely treatment according to the different patterns of TUCSF.

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