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# Incidence patterns of traumatic upper limb fractures in children and adolescents

## Data from medical university-affiliated hospitals in Chongqing, China

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**Abstract**

China's child population ranked second in the world. However, data on the overall patterns and epidemiologic trends of TULFs among children and adolescents in Chongqing, China are scarce. With development of urbanization, motorization, building industry, the incidence patterns of traumatic upper limb fractures in children and adolescents might be about to change. To investigate the incidence patterns of traumatic upper limb fractures in children and adolescents (≤18 years old) according to age (≤3 years old, 3–6 years old, 6–12 years old, and 12–18 years old), gender, time, and etiology groups in Chongqing, China, we retrospectively reviewed 1078 children and adolescents who had traumatic upper limb fractures and who came to our university-affiliated hospitals from 2001 to 2010. The patients were grouped into different age groups, genders, year of admission range groups, and aetiologies. We used Pearson chi-square tests and independent samples *t* tests to assess differences of the grouped data and continuous variables, respectively. This study enrolled 1078 patients (849 males, 229 females) aged 11.0±4.7 years old. The most common aetiologies and fracture sites of patients were low falls (705, 65.4%) and humerus (492, 45.6%). A total of 146 (13.5%) patients suffered a nerve injury, 94 (8.7%) patients sustained associated injuries, and 106 (9.8%) patients sustained complications. The proportion of injuries due to motor vehicle collisions increased with increasing age and year of admission. Female patients presented with significantly higher proportion of injuries due to motor vehicle collisions and significantly lower proportion of injuries due to hit by others. The proportion decreased from 63.2% to 33.3% in humeral fracture, increased from 8.8% to 35.5% in radius fracture, increased from 7.4% to 28.9% in ulna fracture with increasing age. Female patients presented with significantly higher proportion of humeral fracture, clavicle fracture and significantly lower proportion of radius fracture, ulna fracture, and hand fracture. Low falls and humerus fractures were the most common aetiologies and fracture sites. The pattern of traumatic upper limb fractures has specific age, gender, time, and etiology differences.

**Abbreviations:** ASOIs = associated injuries, CT = computed tomography, MRI = magnetic resonance imaging, MVCs = motor vehicle collisions, ND = neurological deficit, ND = neurological deficit, PNI = peripheral nerve injuries, SD = standard deviation, TULFs = traumatic upper limb fractures.

**Keywords:** adolescent, child, public health, trauma, upper limb fractures

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*All listed authors have made substantial contributions to the manuscript.*

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## 1. Introduction

Fractures are common among all types of paediatric injuries and comprise 10% to 25%,[1,2] and the incidence of fracture increased with the year of admission.[3] The patterns of fractures vary between countries and even regions within a country, depending on the local climate, culture, and leisure-time activities.[4–11] Traumatic upper limb fractures (TULFs) account for approximately 80% of all fractures and may result in substantial mortality and morbidity.[12] Some studies have shown an increasing incidence of specific upper limb fracture sites and specific aetiologies in paediatric patients.[10,11,13–18]

In Malmö, pediatric fracture incidence decreased from 1993–1994 to 2005–2006 in girls but not in boys.[12] Researchers pointed out that the 4 upper extremity fractures tended to show greater variations than the 2 lower extremity fractures in the nationwide database in South Korea.[19] Data from children and adolescents with long bone fractures sustained in Switzerland and Norwegian showed that differences in the fracture distribution were sex and age related.[20,21] According to data from the 2015 1% National Population Sample Survey, the child population aged 0 to 17 in China was 271 million in 2015, accounting for 19.7% of the total national population. China's child population ranked second in the world, accounting for 12.9% of the global child population. With development of urbanization, motorization, building industry, the incidence patterns of traumatic upper limb fractures in children and adolescents might be about to change. Data on the overall patterns and epidemiologic trends of TULFs among children and adolescents in China are scarce.

In the present study, we reviewed a multicenter database of TULFs in a population of children and adolescents $\leq$ 18 years of age that occurred over a 10-year period between 2001 and 2010 to address these deficiencies and to provide comprehensive information on this important childhood public health problem in China.[9–11]

## 2. Materials and methods

### 2.1. Study sample

We retrospectively reviewed 2502 children and adolescents ($\leq$18 years old) who presented with fractures between January 2001 and December 2010 and who were admitted to our university-affiliated hospitals (2 tertiary hospitals in Chongqing, China), and among which 1078 patients had TULFs (Figure 1). We made definitive diagnoses of TULFs using X-rays, computed tomography (CT), and/or magnetic resonance imaging (MRI). Data were collected from the 2 biggest hospitals affiliated with the Third Military Medical University in Chongqing, China. The tertiary hospitals are located in the Shapingba district, which is a core district located in the northwest of Chongqing city. We searched the ID numbers of all patients ($\leq$18 years old) presented with fractures in the medical records system, and then the medical records were reviewed and assessed according to the ID numbers to extract the data such as etiology, gender, age, fracture site, neurological deficit, associated injury, complication, and year of admission. Not all the patients were done CT and MRI, but at least 1 test was done to make definitive diagnoses of fracture. Patients with multiple fractures caused by the current injury when they came to our hospitals and multiple admission of the same patient due to different fractures were included in our study. The cases with missing files and caused by self-inflicted trauma and injuries were excluded, neonates with birth injury were included in our study. The patients were grouped into 4 age groups: $\leq$3 years old (neonatal period, infancy stage, and toddler period), 3–6 years old (preschool period), 6–12 years old (junior middle school stage), and 12–18 years old (senior high school stage). The patients were grouped into 5 years of admission range groups: 2001–2002, 2003–2004, 2005–2006, 2007–2008, and 2009–2010. The aetiologies of trauma were grouped into 5 etiology groups: motor vehicle collisions (MVCs) (collisions or falls caused by motor vehicle, the injured could be driver, passenger, or pedestrian), high fall (fall from a high height $\geq$2 m except for MVCs), low fall (fall from a high height $<$ 2 m except for MVCs), mechanical injury (twist injury, pressure injury, or incised injury by machine except for motor vehicle), struck by object, hit by others, and others. Sites of TULFs were divided into humerus, radius, ulna, clavicle, scapula, and hand. Neurological deficit (ND) included central nervous system injury (traumatic brain injury and spinal cord injury) and peripheral nerve injury (cranial nerve injury and spinal nerve injury). Associated injuries (ASOIs) including head injury, lung injury, renal injury, eye injury, cardiac injury, splenic injury, pancreatic injury, intestinal injury, vascular and tendon injury, hemorrhagic shock, osteofascial compartment syndrome, retroperitoneal hematoma, and so on. Complications including fracture mal-union, fracture nonunion, delayed union, fracture site infection, myositis ossificans, osteonecrosis, lung infection, ischemic contracture, decubitus ulcers, traumatic arthritis, deep vein thrombosis, and so on. The study protocol and this manuscript were approved by the committee on ethics and the institutional review board of our institution.

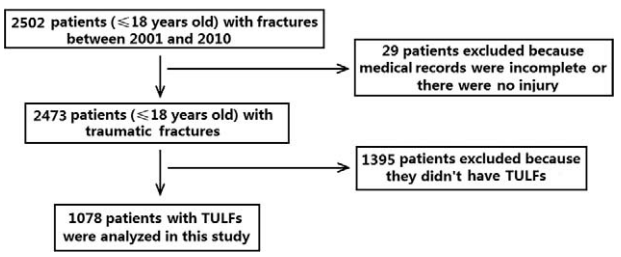


**Figure 1.** Patient flow diagram.

### 2.2. Statistical analysis

All statistical analyses were performed using SPSS version 22.0 (SPSS Inc, Chicago, IL). We used Pearson chi-square tests to assess differences in sex distribution and clinical characteristics between the 2 groups. Continuous variables, such as age, were tested using the 1-sample Kolmogorov–Smirnov test for normal distribution. Differences in the continuous variables such as mean age between any 2 groups were evaluated using independent samples *t* tests. The variables are expressed as mean $\pm$ standard deviation (SD).

## 3. Results

The overall annual proportion of TULFs was (101.6 $\pm$ 47.5) patients per 100,000 hospital admissions per 2-year period. Annual proportion increased from 22.9 patients (2001–2002) to 141.6 patients (2005–2006) and then decreased to 105.5 patients (2009–2010) with year of admission per 100,000 hospital admissions per 2-year period. The incidence had an obvious

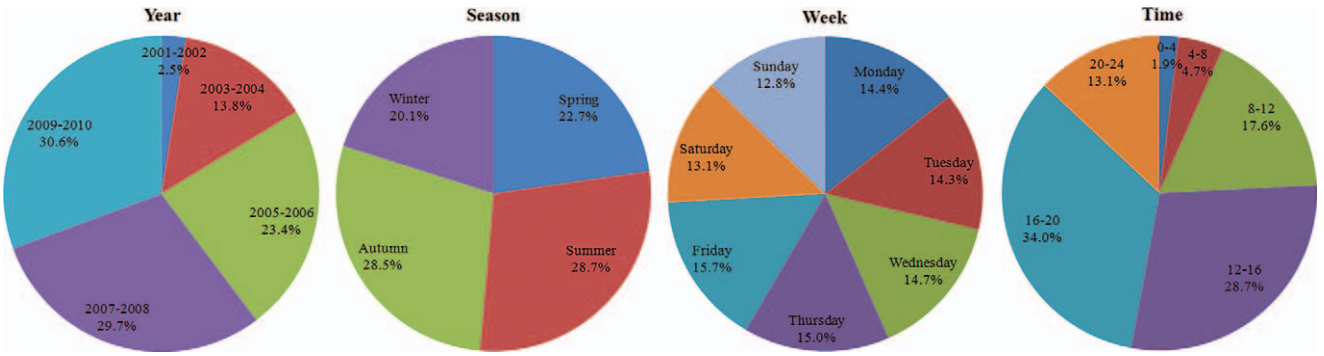


**Figure 2.** Year, season, week, and time distribution of all 1078 cases.

seasonal, time variation, and a little week variation, with peaks in summer (28.7%), autumn (28.5%), 16:00–20:00 PM (34.0%) and Friday (15.7%) (Figure 2).

The incidence peaked around the periods of 12 to 18 years in the male, 6 to 12 years in the female (Table 1). The most common fracture sites were humerus and radius in the patients caused by low fall, clavicle, and humerus in the patients caused by MVCs, radius, and humerus in the patients caused by high falls, hand in the patients caused by mechanical injury. The most common causes were low falls and mechanical injury in children aged ≤3 years, low falls and high falls in children aged 3 to 6 years, low falls and high falls in children aged 6 to 12 years, low falls and MVCs in children aged 12 to 18 years. With increasing age the proportion of injuries due to MVCs and hit by others increased. With increasing year of admission the proportion of injuries due to MVCs, and low fall increased.

The proportion of humeral fracture was the largest in the low fall group (52.3%) and lowest in the struck by object group (15.2%). The proportion of radial fracture was the largest in the high fall group (48.1%) and lowest in the MVCs group (15.2%). The proportion of ulnar fracture was the largest in the high fall group (36.8%) and lowest in the mechanical injury group (10.0%). The proportion of clavicle fracture was the largest in the MVCs group (40.8%) and lowest in the mechanical injury group (2.5%). The proportion of hand fracture was the largest in the struck by object group (72.7%) and mechanical injury group (72.5%) and lowest in the low fall group (3.1%) (Table 1).

Among all the patients, the most common fracture sites were humerus and radius (Figure 3). The most common fracture sites were humerus and hand in the ≤3-year-old patients, humerus in the 3 to 6-year-old patients, humerus and radius in the 6 to 12-year-old patients, radius and humerus in the 12 to 18-year-old patients. The proportion decreased from 63.2% to 33.3% in humeral fracture, increased from 8.8% to 35.5% in radius fracture, increased from 7.4% to 28.9% in ulna fracture with increasing age. During all periods the occurrence increased with

**Table 1**

**The epidemiology of traumatic upper limb fractures according to different etiologies.**

| Aetiologies | Low fall | MVCs | High fall | Mechanical injury | Struck by object | Hit by others | Others | Total |
|---|---|---|---|---|---|---|---|---|
| Total (n) | 705 | 125 | 106 | 40 | 33 | 31 | 38 | 1078 |
| Male/female (n, %) | 554/151 (3.7) | 85/40 (2.1) | 87/19 (4.6) | 35/5 (7.0) | 29/4 (7.3) | 30/1 (30.0) | 29/9 (3.2) | 849/229 (3.7) |
| Mean age (mean ± SD) | 10.4 ± 4.4 | 12.0 ± 4.8 | 11.0 ± 4.5 | 13.8 ± 6.5 | 11.1 ± 5.5 | 15.4 ± 2.6 | 12.3 ± 5.1 | 11.0 ± 4.7 |
| Age range (n, %) | | | | | | | | |
| ≤3 | 44 (6.2) | 5 (4.0) | 3 (2.8) | 8 (20.0) | 5 (15.2) | 0 | 3 (7.9) | 68 (6.3) |
| 3–6 | 108 (15.3) | 14 (11.2) | 17 (16.0) | 1 (2.5) | 2 (6.1) | 0 | 2 (5.3) | 144 (13.4) |
| 6–12 | 294 (41.7) | 41 (32.8) | 46 (43.4) | 1 (2.5) | 11 (33.3) | 3 (9.7) | 14 (36.8) | 410 (38.0) |
| 12–18 | 259 (36.7) | 65 (52.0) | 40 (37.7) | 30 (75.0) | 15 (45.5) | 28 (90.3) | 19 (50.0) | 456 (42.3) |
| Year range (n, %) | | | | | | | | |
| 2001–2002 | 22 (3.1) | 1 (0.8) | 4 (3.8) | 0 | 0 | 0 | 0 | 27 (2.5) |
| 2003–2004 | 92 (13.0) | 21 (16.8) | 18 (17.0) | 6 (15.0) | 5 (15.2) | 3 (9.7) | 4 (10.5) | 149 (13.8) |
| 2005–2006 | 157 (22.3) | 31 (24.8) | 17 (16.0) | 16 (40.0) | 8 (24.2) | 16 (51.6) | 7 (18.4) | 252 (23.4) |
| 2007–2008 | 198 (28.1) | 36 (28.8) | 35 (33.0) | 15 (37.5) | 13 (39.4) | 7 (22.6) | 16 (42.1) | 320 (29.7) |
| 2009–2010 | 236 (33.5) | 36 (28.8) | 32 (30.2) | 3 (7.5) | 7 (21.2) | 5 (16.1) | 11 (28.9) | 330 (30.6) |
| Fracture sites (n, %) | | | | | | | | |
| Humerus | 369 (52.3) | 46 (36.8) | 45 (42.5) | 8 (20.0) | 5 (15.2) | 5 (16.1) | 14 (36.8) | 492 (45.6) |
| Radius | 221 (31.3) | 19 (15.2) | 51 (48.1) | 8 (20.0) | 0 | 6 (19.4) | 7 (18.4) | 312 (28.9) |
| Ulna | 192 (27.2) | 15 (12.0) | 39 (36.8) | 4 (10.0) | 0 | 10 (32.3) | 4 (10.5) | 264 (24.5) |
| Clavicle | 56 (7.9) | 51 (40.8) | 12 (11.3) | 1 (2.5) | 4 (12.1) | 1 (3.2) | 7 (18.4) | 132 (12.2) |
| Scapula | 0 | 3 (2.4) | 1 (0.9) | 2 (5.0) | 0 | 1 (3.2) | 0 | 7 (0.6) |
| Hand | 22 (3.1) | 14 (11.2) | 4 (3.8) | 29 (72.5) | 24 (72.7) | 13 (41.9) | 10 (26.3) | 116 (10.8) |
| ND (n, %) | 55 (7.8) | 41 (32.8) | 34 (32.1) | 8 (20.0) | 1 (3.0) | 3 (9.7) | 4 (10.5) | 146 (13.5) |
| PNI (n, %) | 49 (7.0) | 20 (16.0) | 13 (12.3) | 8 (20.0) | 1 (3.0) | 3 (9.7) | 4 (10.5) | 98 (9.1) |

MVCs = motor vehicle collisions, ND = neurological deficit, PNI = peripheral nerve injuries.

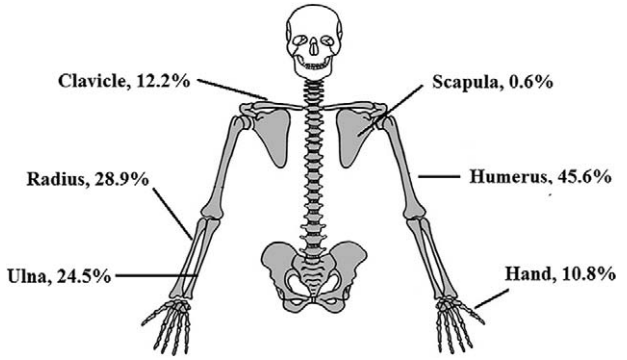


**Figure 3.** Fracture site distribution of all 1078 patients.

increasing age group and a male preponderance was observed in all age groups (Table 2).

Overall, the most common aetiologies were low falls, followed by MVCs and high falls. The most common aetiologies were low fall and MVCs in female patients, low fall and high fall in male patients. Female patients presented with significantly higher proportions of ≤3-year-old age range ($P=.021$), 3 to 6-year-old age group ($P<.001$), and 6 to 12-year-old age group ($P=.048$), significantly lower proportions of 12 to 18-year-old age group ($P<.001$) than male patients. Female patients presented with significantly higher proportion of injuries due to MVCs and significantly lower proportion of injuries due to hit by others. Female patients presented with significantly higher proportion of humeral fracture, clavicle fracture and significantly lower proportion of radius fracture, ulna fracture, and hand fracture (Table 3).

A total of 146 (13.5%) patients suffered neurological deficit (ND), 94 (8.7%) patients sustained ASOIs, and 106 (9.8%) patients sustained complications (Figure 4). Among the patients who presented with ND, peripheral nerve injuries (PNI) were seen in 98 patients. The frequency of ND and PNI increased with age.

## 4. Discussion

In the current study, pediatric and adolescent traumatic fractures were evaluated in 2473 children of 18 years of age or less with a total of 1078 upper limb fractures over a 10-year period. Of the patients with TULFs, age group of 12 to 18-years old accounted for the largest proportion. The percentage of patients with TULFs increased steadily with age. This phenomenon may be explained by increased activity, by more aggressive sports activities in this age group. The most common fracture sites were humerus and radius, followed by ulna. Similar to previous reports, distal forearm was the most common fracture subtype overall.[12,20,22] Distal forearm were the most common fracture sites could be explained by low falls (the most common etiology) during which patients will fall on their outstretched hand, they are most likely to break the radius and ulna.

The most common causes were low falls, which was consistent with previous study.[16,18,20] The most common mechanism for pediatric forearm fractures was fall-related (83%) whereas direct trauma caused 10% of fractures.[16] The leading cause of pediatric long bone fractures was falls (27%), followed by accidents occurring during leisure activities (25%).[20] With increasing age the proportion of injuries due to MVCs and hit by others increased. This phenomenon may be explained by the motorization in city and impulsive personality of adolescent, so it is necessary to discuss and research drivers' education in city automobile's times and the psychological education of adolescent. While young children usually sustain injuries from low-velocity forces such as falls, older children are more likely to be exposed to high-velocity forces such as MVCs. Female patients presented with significantly higher proportion of injuries due to

**Table 2**

**The epidemiology of traumatic upper limb fractures according to different age range groups.**

| Year range | ≤3 | 3–6 | 6–12 | 12–18 |
|---|---|---|---|---|
| Total (n) | 68 | 144 | 410 | 456 |
| Male/female (n, %) | 46/22 (2.1) | 94/50 (1.9) | 310/100 (3.1)† | 399/57 (7.0)*,†,‡ |
| Mean age (mean ± SD) | 2.3 ± 0.8 | 5.1 ± 0.8* | 9.5 ± 1.7*,† | 15.6 ± 1.8*,†,‡ |
| Fracture sites (n, %) | | | | |
| Humerus | 43 (63.2) | 89 (61.8) | 208 (50.7) | 152 (33.3)*,†,‡ |
| Radius | 6 (8.8) | 23 (16.0) | 121 (29.5)*,† | 162 (35.5)*,† |
| Ulna | 5 (7.4) | 22 (15.3) | 105 (25.6)*,† | 132 (28.9)*,† |
| Clavicle | 5 (7.4) | 23 (16.0) | 53 (12.9) | 51 (11.2) |
| Scapula | 0 | 0 | 2 (0.5) | 5 (1.1) |
| Hand | 15 (22.1) | 3 (2.1)* | 18 (4.4)* | 80 (17.5)†,‡ |
| ND (n, %) | 2 (2.9) | 14 (9.7) | 52 (12.7)* | 78 (17.1)*,† |
| PNI (n, %) | 1 (1.5) | 6 (4.2) | 35 (8.5)* | 56 (12.3)*,† |

ND = neurological deficit, PNI = peripheral nerve injuries.
* Significant difference compared to ≤3 age group.
† Significant difference compared to 3–6 age group.
‡ Significant difference compared to 6–12 age group.

**Table 3**

**The epidemiology of traumatic upper limb fractures according to different genders.**

| Etiologies | Male | Female | *P* |
|---|---|---|---|
| Total (n) | 849 | 229 | <.001 |
| Mean age (mean ± SD) | 11.4 ± 4.6 | 9.4 ± 4.6 | <.001 |
| Age range (n, %) | | | |
| ≤3 | 46 (5.4) | 22 (9.6) | .021 |
| 3–6 | 94 (11.1) | 50 (21.8) | <.001 |
| 6–12 | 310 (36.5) | 100 (43.7) | .048 |
| 12–18 | 399 (47.0) | 57 (24.9) | <.001 |
| Year range (n, %) | | | |
| 2001–2002 | 17 (2.0) | 10 (4.4) | .042 |
| 2003–2004 | 125 (14.7) | 24 (10.5) | .099 |
| 2005–2006 | 202 (23.8) | 50 (21.8) | .534 |
| 2007–2008 | 239 (28.2) | 81 (35.4) | .034 |
| 2009–2010 | 266 (31.3) | 64 (28.0) | .324 |
| Etiologies (n, %) | | | |
| Low fall | 554 (65.3) | 151 (66.0) | .847 |
| High fall | 87 (10.3) | 19 (8.3) | .379 |
| MVCs | 85 (10.0) | 40 (17.5) | .002 |
| Mechanical injury | 35 (4.1) | 5 (2.2) | .168 |
| Struck by object | 29 (3.4) | 4 (1.8) | .193 |
| Hit by others | 30 (3.5) | 1 (0.4) | .013 |
| Others | 29 (3.4) | 9 (3.9) | .708 |
| Fracture sites (n, %) | | | |
| Humerus | 369 (43.5) | 123 (53.7) | .006 |
| Radius | 271 (31.9) | 41 (17.9) | <.001 |
| Ulna | 225 (26.5) | 39 (17.0) | .003 |
| Clavicle | 90 (10.6) | 42 (18.3) | .002 |
| Scapula | 5 (0.6) | 2 (0.9) | .634 |
| Hand | 104 (12.2) | 12 (5.2) | .002 |
| ND (n, %) | 118 (13.9) | 28 (12.2) | .512 |
| PNI (n, %) | 83 (9.8) | 15 (6.6) | .132 |

MVCs = motor vehicle collisions, ND = neurological deficit, PNI = peripheral nerve injuries.

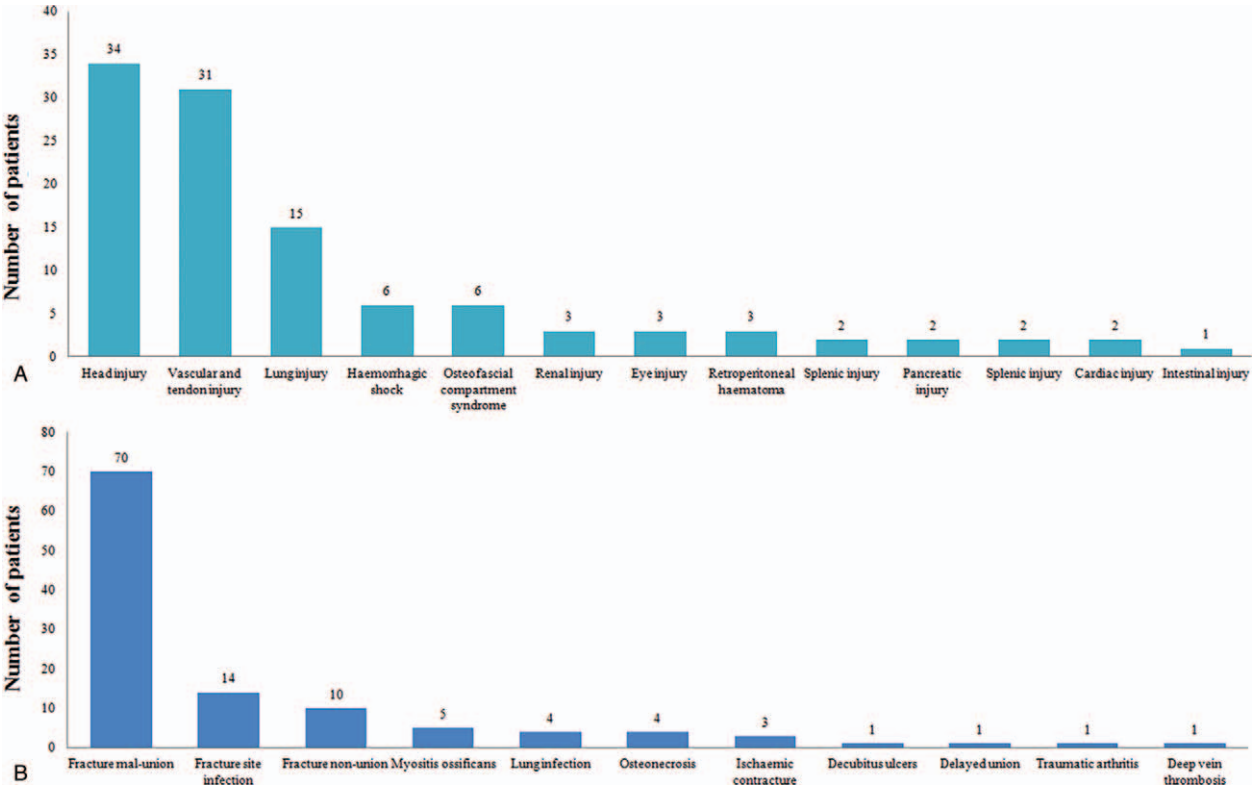


**Figure 4.** Number of patients presented with associated injuries (A) and complications (B).

MVCs and significantly lower proportion of injuries due to hit by others. This phenomenon may be explained by that the females are more likely to be exposed to high-velocity forces as pedestrianin or passengers (all female patients caused by MVCs were all pedestrianin or passengers in our study) during MVCs and males are more impulsive than females to fight with others.

The incidences had an obvious seasonal variation, with peaks in summer and autumn. Previous study showed that the incidences of distal radius fractures in Japanese children and adolescents had an obvious monthly variation, with peaks in spring and autumn.[13] Some study showed that the overall incidence figures were dominated by an increase in children's wrist and forearm fractures in spring and summer.[17] The incidences also had week and time variation, with peaks in Friday, 16:00–20:00 PM. These are the seasons and times of great opportunity for outdoor and sports activities, short trips, and recreation in general, thus tending to a higher chance of trauma. We believe that the pattern of traumatic fractures among children and adolescents is partly explained by changes in the activity patterns of children over time and whether that time is during rush hour or dismissal times. We should pay much more attention to the prevention of fractures during rush hour or dismissal times especially on Friday and at 16:00–20:00 PM.

Previous studies showed the incidence of distal forearm fractures in children and adolescents has increased.[13–15,18] Annual proportion of TULFs in the current study increased from 22.9 patients to 141.6 patients and then decreased to 105.5 patients with year of admission per 100,000 hospital admissions per 2-year period. Our findings emphasize that a multifactorial approach to the prevention of upper limb fractures is necessary if the incidence of these fractures is to be reduced through medical or public health interventions. The data we have presented here on the population burden of upper limb fractures may be useful to public health program planners in prioritizing funding for the prevention of upper limb fractures as well as for developing approaches to the prevention of upper limb fractures in specific segments of the population.

This study has several limitations. It was limited by the retrospective study design, the small sample size, and selection bias, because this study included patients who were referred to our teaching hospitals. But, despite these limitations, the current study was the latest study to show the incidence patterns of TULFs in children and adolescents according to age, gender, time, and etiology groups in China. Researchers can prevent or reduce the happening of TULFs through simple environmental modifications and education. In the near future, other investigators worldwide will undertake multicenter and large-scale collaborative studies to produce more comprehensive information regarding the incidence patterns of TULFs.

## 5. Conclusion

Low falls and humerus fractures were the most common etiologies and fracture sites. The proportion of injuries due to MVCs increased with increasing age and year of admission. Female patients presented with significantly higher proportion of injuries due to MVCs and significantly lower proportion of injuries due to hit by others. Female patients presented with significantly higher proportion of humeral fracture, clavicle fracture and significantly lower proportion of radius fracture, ulna fracture, and hand fracture. The pattern of traumatic upper limb fractures has specific age, gender, time, and etiology

differences. We should develop targeted prevention strategies according to the characteristics.

## Author contributions

**Conceptualization:** Liangbi Xiang.
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**Software:** Lan Ou, Jun Liu.
**Supervision:** Hua Yang, Changqing Li, Yue Zhou, Liangbi Xiang.
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**Writing – review & editing:** Hua Yang, Can Cao, Yue Zhou, Liangbi Xiang.

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