Incidence, characteristics, and treatments of traumatic open fractures in children and adolescents
A retrospective observational study

Hongwei Wang, PhD, Hong Yuan, MS, Lu Liu, MS, Deluo Wu, MD, Lan Ou, MD, Changqing Li, PhD, Hailong Yu, PhD

Abstract

We aimed to investigate the incidence, characteristics, and treatments of open fractures in children and adolescents (≤18 years old).

We retrospectively reviewed the records of 2418 children and adolescents who presented with traumatic fractures and were admitted to our university-affiliated hospitals, among which 206 patients (8.5%) presented with open fractures. The patients' clinical and radiographic records were reviewed, and the age, gender, cause of injury, injury season, injury week, associated injuries and complications were collected.

This study enrolled 1789 males (74.0%) and 629 females (26.0%) with an average age of 11.2 ± 5.0 years. The patients were divided into an open fracture group (OF group, n = 206) and a group with no open fracture (No-OF group, n = 2212). There were 206 patients (8.5%) who presented with open fractures and the most common fracture sites were the tibia (31.1%, 64/206) and fibula (20.9%, 43/206). The patients in the OF group presented with higher frequency of emergency admission (P < 0.001), self-supporting medical insurance (P < 0.001), MVCs (P < 0.001), wounded by machine (P < 0.001), struck by object (P < 0.001), hurt/cut by others (P < 0.001), lower limb fractures (P < 0.001), multiple fractures (P = 0.010), associated injuries (P < 0.001) and wound infection (P = 0.003) than the patients in the No-OF group. The most common complication were wound infection (5.8%) and pneumonia (1.0%) in the OF group, wound infection (2.1%) and pressure sores (2.0%) in the No-OF group. Multivariate logistic regression analysis indicated that mechanical trauma (OR = 64.229, P < 0.001), being hurt/cut by others (OR = 26.757, P < 0.001), and being struck by an object (OR = 15.345, P < 0.001) were stronger risk factors for open fracture than were low falls, additionally, lower limb fractures (OR = 5.970, P < 0.001), upper limb fractures (OR = 5.865, P < 0.001) and multiple fractures (OR = 5.414, P < 0.001) were stronger risk factors than craniofacial fractures for open fractures. The frequency of surgical treatment for the patients with traumatic open fractures (87.9%, 181/206) was significantly higher than those without open fractures (72.2%, 1596/2212) (P < 0.001). The hospital stays and fees for surgical treatment for the patients with traumatic open fractures were significantly higher than those without open fractures (P < 0.001).

Etiology (especially being injured by a machine or being hurt/cut by others) and the fracture site (including lower limb fractures and upper limb fractures) were independent risk factors for open fractures. Traumatic open fractures presented with higher surgical treatment rate, hospital stays and fees.

Abbreviations: ASOIs = associated injuries, CFFs = craniofacial fractures, CT = computed tomography, LLFs = lower limb fractures, MFs = multiple fractures, MRI = magnetic resonance imaging, MVCs = motor vehicle collisions, NIs = nerve injuries, OFs = open fractures, RSFs = fractures of rib and sternum, SFs = spinal fractures, SD = standard deviation, TFs = traumatic fractures, ULFs = upper limb fractures, VIs = visceral injuries.

Keywords: adolescent, children, fracture, open fracture, traumatic

Hongwei Wang, Hong Yuan, and Lu Liu contributed equally to this work.

Funding: This work was supported by the Foundation of the Liaoning Provincial Natural Science Foundation of China (2019-ZD-1063) and the Shenyang Science and Technology Project (21-173-9-70).

All listed authors have made substantial contributions to the manuscript and do not have any conflicts of interest. All authors read and approved the final manuscript.

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

* Department of Orthopedics, General Hospital of Northern Theater Command of Chinese PLA, Shenyang, Liaoning, China
1 Department of Research and Training, General Hospital of Northern Theater Command of Chinese PLA, Shenyang, Liaoning, China
2 Department of Orthopedics, Affiliated Hospital of Yangzhou University, Yangzhou, Jiangsu, China
3 Department of Radiology, Southwest Hospital, Army Medical University, Chongqing, China
4 Department of Orthopedics, Xinqiao Hospital, Army Medical University, Chongqing, China.

*Correspondence: Hailong Yu (e-mail: yuhailong118@aliyun.com).

Copyright © 2022 the Author(s). Published by Wolters Kluwer Health, Inc. This is an open-access article distributed under the terms of the Creative Commons Attribution-Non Commercial License 4.0 (CCBY-NC), where it is permissible to download, share, remix, transform, and buildup the work provided it is properly cited. The work cannot be used commercially without permission from the journal.

How to cite this article: Wang H, Yuan H, Liu L, Wu D, Ou L, Li C, Yu H. Incidence, characteristics, and treatments of traumatic open fractures in children and adolescents: a retrospective observational study. Medicine 2022;101:26(e29828).

Received: 25 February 2022 / Received in final form: 13 May 2022 / Accepted: 31 May 2022

http://dx.doi.org/10.1097/MD.0000000000029828
1. Introduction
Fractures account for 10% to 25% of paediatric injuries.\[^{1,2}\] The patterns of fractures vary between countries and even between regions within a country, depending on the local climate, culture, and leisure-time activities.\[^{1-8}\] The epidemiology of paediatric open fractures (OFs) is still not completely understood. The incidence varies from centre to center, the OFs comprise 2% to 9% of all paediatric fractures.\[^{9-12}\] Data about the incidence, incidence varies from centre to center, the OFs comprise 2% of all paediatric fractures.\[^{9-12}\] The incidence and characteristics of treatments of OFs in children and adolescents (≤18 years old) in China are scarce. It is very important to investigate the incidence, characteristics and treatments of OFs. At the same time, we discuss the associated injuries and complications, which is helpful for discussing the early, timely diagnosis and treatment. It is important for the allocation of public resources, the development of preventative strategies and efficient diagnosis and treatment.

In the present study, we reviewed a multicentre (2 tertiary hospitals in Chongqing, China) database of TFs (traumatic fractures) in a population of children and adolescents ≤18 years of age to address these deficiencies and to provide comprehensive information on this important childhood public health problem in China. Three topics have been discussed in depth: (1) Incidence and characteristics (including associated injuries and complications) of traumatic OFs in children and adolescents (≤18 years old); (2) Risk factors for traumatic OFs in children and adolescents (≤18 years old); (3) Treatments of traumatic OFs (including treatment technique, intensive care unit stays, hospital stays and fees).

2. Materials and methods

2.1. Study population
We have studied 2505 patients from a population of children and adolescents (≤18 years old) who had TFs between January 2013 and December 2020 and who were admitted to our university-affiliated hospitals. We used X-rays, computed tomography (CT) and magnetic resonance imaging (MRI) to make definitive diagnoses of TFs in patients who were children or adolescents (≤18 years old). The medical records were reviewed and assessed by 2 independent persons who did not participate in treating any of the patients. The inclusion criteria for patients in this study were as follows: (i) patients who presented with fractures on X-ray, CT, and/or MRI and (ii) hospitalization for the treatment of TFs between January 2013 and December 2020. The exclusion criteria were as follows: (i) patients with pathologic fractures and (ii) repeated hospitalizations due to injuries at the same fracture site. There were 73 cases with pathologic fracture and 14 cases with repeated hospitalizations due to injuries at the same fracture site. Finally, our study included 2418 patients who had TFs between January 2013 and December 2020.

2.2. General characteristics
The patients were classified into 3 age groups: ≤6 years old (neonatal period, infancy stage, toddler period, and preschool period), 6 to 12 years old (junior middle school stage) and 12 to 18 years old (senior high school stage). The patients were also classified into 7 groups based on the etiology of the trauma: motor vehicle collisions (MVCs), high fall (fall from a high height ≥2 m unrelated to MVCs), low fall (fall from a high height <2 m unrelated to MVCs), injured by a machine, struck by an object, hurt/cut by others and other etiologies. The sites of fractures included lower limb fractures (LLFs), upper limb fractures (ULFs), craniofacial fractures (CFFs), spinal fractures (SFs), fractures of rib and sternum (RSFs) and multiple fractures (MFs). The sites of the lower limb fractures (LLFs) were classified as the femur, tibia, fibula, pelvis and foot. The sites of the upper limb fractures (ULFs) were classified as the humerus, radius, ulna, clavicle, scapula and hand.

2.3. Associated injuries and complications
Associated injuries (ASOIs) include head injury, lung injury, renal injury, hemorrhagic shock, osteofascial compartment syndrome, retroperitoneal hematoma and so on. Complications included fracture malunion, fracture nonunion, delayed union, fracture site infection, decubitus ulcers, traumatic arthritis, deep vein thrombosis, and so on. Visceral injuries (VI) included craniocebral injury, intrathoracic injuries and intraabdominal injuries. Nerve injuries (NIs) included central nervous system injury (traumatic brain injury and spinal cord injury) and peripheral nerve injury (cranial nerve injury and spinal nerve injury). The study protocol and this manuscript were approved by the ethics committee and the institutional review board of our institution.

2.4. Statistical analysis
All statistic analyses were performed using SPSS version 22.0 (SPSS, Inc., Chicago, IL). We used Pearson chi-square tests to assess differences in age, sex, distribution and clinical characteristics between the 2 groups of patients with and without open fractures. Continuous variables such as current age were examined using the 1-sample Kolmogorov-Smirnov test for normally distributed variables; these variables are expressed as the mean ± standard deviation (SD). Differences in the continuous variables between the 2 groups were evaluated using independent samples t-tests. Univariate and multivariate logistic regression analyses were used to evaluate associations between the clinicopathological features and the prevalence of open fractures.

3. Results

3.1. General characteristics of traumatic fracture
This study enrolled 1789 males (74.0%) and 629 females (26.0%) with an average age of 11.2 ± 5.0 years old. Overall, the most common etiologies were low falls (42.5%, 1027/2418), followed by MVCs (29.5%, 713/2418) and high falls (14.4%, 348/2418). Among the patients, the most common fracture sites were ULFs (38.9%, 940/2418) and LLFs (31.3%, 758/2418), followed by CFFs (17.7%, 427/2418). A total of 645 (26.7%) patients sustained ASOIs, and 197 (8.1%) patients had experienced complications (Table 1).

The etiologies such as being injured by a machine, being hurt/cut by others and being struck by object accounted for 2.0% (48/2418), 3.1% (74/2418), 4.2% (101/2418). Among the patients injured by a machine, 30 persons (62.5%, 30/48) injured during working. Among the patients struck by object, 22 persons (21.8%, 22/101) injured during working. Among the patients hurt/cut by others, 24 persons (32.4%, 24/74) were cut by others (Table 2).

3.2. Incidence and characteristics of traumatic open fracture
There were 206 patients (8.5%) who presented with an open fracture: 94 patients had an open fracture on the left side (45.6%), 103 patients had an open fracture on the right side (51.0%), and 7 patients had open fractures on both sides (3.4%). Overall, the most common etiologies were MVCs (45.6%, 94/206), followed by being injured by a machine (13.1%, 27/206). The most common fracture sites were lower extremity fractures (55.3%, 114/206) and upper extremity fractures (44.7%, 92/206). The most common fracture sites were...
tibial fractures (31.6%, 65/206), fibular fractures (22.8%, 47/206), radial fractures (13.6%, 28/206), ulnar fractures (13.1%, 27/206), humeral fractures (13.1%, 27/206), and femoral fractures (12.6%, 26/206). The most common complication were wound infection (5.8%) and pneumonia (1.0%) in the OF group, wound infection (2.1%) and pressure sores (2.0%) in the No-OF group (Table 1).

### 3.3. Risk factors for traumatic open fracture

The patients in the OF group presented with higher frequency of emergency admission ($P < 0.001$), self-supporting medical insurance ($P < 0.001$), MVCs ($P < 0.001$), wounded by machine ($P < 0.001$), struck by object ($P < 0.001$), hurt/cut by others ($P < 0.001$), lower limb fractures ($P < 0.001$), multiple fractures ($P < 0.001$), and multiple complications ($P < 0.001$). This finding suggests that traumatic open fractures are associated with specific risk factors and should be managed with caution to prevent complications.

### Table 1

| General characteristics of traumatic fractures and open fracture. | Total | OF group | No-OF group | $\chi^2$ | $P$ |
|---|---|---|---|---|---|
| Total | 2418 | 206 | 2212 | | |
| Gender | | | | | |
| Male | 1789 (74.0) | 148 (71.8) | 1641 (74.2) | 0.537 | 0.464 |
| Female | 629 (26.0) | 58 (28.2) | 571 (25.8) | | |
| Admission to hospital | | | | | |
| Emergency admission | 1098 (45.4) | 147 (71.4) | 951 (43.0) | 60.032 | <0.001 |
| Outpatient admission | 1320 (54.6) | 59 (28.6) | 1261 (57.0) | | |
| Medical insurance | | | | | |
| Self-supporting | 1376 (56.9) | 149 (72.3) | 1227 (55.5) | 21.162 | <0.001 |
| Medicare | 1042 (43.1) | 57 (27.7) | 985 (44.5) | | |
| Age | 11.2 ± 5.0 | 11.8 ± 5.2 | 11.1 ± 5.0 | | |
| 0–6 | 550 (22.7) | 45 (21.8) | 505 (22.8) | 3.448 | 0.178 |
| 6–12 | 764 (31.6) | 55 (26.7) | 709 (32.1) | | |
| 12–18 | 1104 (45.7) | 106 (51.5) | 998 (45.1) | | |
| Injury season | | | | | |
| Spring | 608 (25.1) | 49 (23.8) | 559 (25.3) | 0.354 | 0.594 |
| Summer | 657 (27.2) | 59 (28.6) | 598 (27.0) | | |
| Autumn | 629 (26.0) | 53 (25.7) | 576 (26.0) | | |
| Winter | 524 (21.7) | 45 (21.8) | 479 (21.7) | | |
| Injury week | | | | | |
| Monday | 353 (14.6) | 26 (12.6) | 327 (14.8) | 6.419 | 0.378 |
| Tuesday | 358 (14.8) | 30 (15.6) | 328 (14.6) | | |
| Wednesday | 346 (14.3) | 30 (14.6) | 316 (14.3) | | |
| Thursday | 330 (13.6) | 22 (10.7) | 308 (13.9) | | |
| Friday | 348 (14.4) | 29 (14.6) | 319 (14.4) | | |
| Saturday | 345 (14.3) | 30 (14.6) | 315 (14.3) | | |
| Sunday | 336 (13.9) | 25 (12.1) | 311 (14.1) | | |
| Injury cause | | | | | |
| MVCs | 713 (29.5) | 69 (34.1) | 644 (29.1) | 27.384 | <0.001 |
| Wounded by machine | 48 (2.0) | 27 (13.1) | 21 (9.0) | 136.974 | <0.001 |
| High fall (>2m) | 38 (1.6) | 22 (13.1) | 16 (7.5) | 1.628 | 0.202 |
| Low fall (<2m) | 1027 (42.5) | 21 (10.2) | 1006 (45.5) | 94.588 | <0.001 |
| Struck by object | 101 (4.2) | 20 (9.7) | 81 (3.7) | 15.738 | <0.001 |
| Hurt/cut by others | 74 (3.1) | 17 (8.3) | 57 (2.6) | 18.593 | <0.001 |
| Others | 107 (4.4) | 4 (1.9) | 103 (4.7) | 2.673 | 0.102 |
| ASOIs - fracture | | | | | |
| LLFs | 758 (31.3) | 90 (43.7) | 668 (30.2) | 15.315 | <0.001 |
| ULFs | 940 (38.9) | 76 (36.4) | 865 (39.1) | 0.469 | 0.493 |
| CFFs | 427 (17.7) | 16 (7.3) | 411 (18.7) | 19.101 | <0.001 |
| SFs | 78 (3.2) | 0 (0) | 78 (3.3) | 6.419 | 0.011 |
| RSFs | 80 (3.3) | 0 (0) | 80 (3.3) | 0.053 | 0.818 |
| MFs | 207 (8.6) | 28 (13.6) | 179 (8.1) | 6.597 | 0.010 |
| ASOIs - Vs | | | | | |
| Craniocerebral injury | 293 (12.1) | 18 (8.7) | 275 (12.4) | 2.081 | 0.149 |
| Intrathoracic injuries | 76 (3.1) | 5 (2.4) | 71 (3.2) | 0.166 | 0.684 |
| Intraabdominal injuries | 45 (1.9) | 4 (1.9) | 41 (1.9) | 0.008 | 0.929 |
| ASOIs - NIs | | | | | |
| Craniocerebral injury | 293 (12.1) | 18 (8.7) | 275 (12.4) | 2.081 | 0.149 |
| Spinal cord injury | 46 (1.9) | 2 (1.0) | 44 (1.9) | 0.517 | 0.472 |
| Cerebral palsy | 25 (1.0) | 0 (0) | 25 (1.1) | 1.378 | 0.241 |
| Spinal cord injury | 127 (5.3) | 33 (16.0) | 94 (4.2) | 50.121 | <0.001 |
| Coma after injury | 224 (9.3) | 16 (7.8) | 208 (9.4) | 0.421 | 0.516 |
| ASOIs | 645 (26.7) | 88 (42.7) | 557 (25.2) | 29.633 | <0.001 |
| Main complications | | | | | |
| Deep venous thrombosis | 1 (0.04) | 0 | 1 (0.04) | 0.000 | 1.000 |
| Pneumonia | 150 (6.2) | 2 (1.0) | 148 (6.7) | 0.042 | 0.837 |
| Pressure sores | 50 (2.0) | 0 | 50 (2.0) | 0.000 | 1.000 |
| Wound infection | 60 (2.5) | 12 (5.8) | 48 (2.1) | 8.949 | 0.003 |
| Complications | 19 (8.1) | 17 (8.3) | 180 (8.1) | 0.003 | 0.954 |

ASOIs = associated injuries, CFFs = craniofacial fractures, LLFs = lower limb fractures, MFs = multiple fractures, MVCs = motor vehicle collisions, NI = nerve injuries, RSFs = fractures of rib and sternum, SFs = spinal fractures, ULFs = upper limb fractures, VI = visceral injuries.
fractures ($P = 0.010$), associated injuries ($P < 0.001$) and wound infection ($P = 0.003$) then the patients in the No-OF group. Multivariate logistic regression analysis indicated that mechanical trauma (OR = 64.229, $P < 0.001$), being hurt/cut by others (OR = 26.757, $P < 0.001$), and being struck by an object (OR = 15.345, $P < 0.001$) were stronger independent risk factors for open fracture than low fall; moreover, lower limb fracture (OR = 5.970, $P < 0.001$), upper limb fracture (OR = 5.865, $P < 0.001$) and multiple fractures (OR = 5.414, $P < 0.001$) were stronger independent risk factors for open fracture than craniofacial fractures (Table 3).

### 3.4. Treatments of traumatic open fracture

The frequency of surgical treatment (ST) among the patients who presented with traumatic open fractures (87.9%, 181/206) was significantly higher than the frequency among patients without open fractures (72.2%, 1596/2212). The hospital stays and fees for surgical treatment for the patients who presented with traumatic open fractures were significantly higher than those for the patients without open fractures (Table 4).

### 4. Discussion

#### 4.1. Incidence and characteristics of traumatic open fracture

The incidence of traumatic open fracture varies from center to center, the open fractures comprise 2% to 9% of all pediatric fractures.[9–12] In the current study, the incidence of traumatic open fracture was 8.5%. Consistent with previous studies showing that most cases of pediatric open fractures are a result of high-velocity trauma, including motor accidents and falls from a height,[13] the most common etiologies in the current study were MVCs (45.6%), being injured by a machine (13.1%) and high fall (11.2%). Open fractures are more common in boys (71.8%). Most open fractures involve the forearm and tibia. In a retrospective multicentric analysis of pediatric fractures, researchers reported that 34% of open fractures involved the tibia/fibula and 32% involved the forearm, followed by the hand (10%), femur (6.7%) and humerus (6.5%).[14] In the current study, the most common open fracture sites were the tibia (31.6%), fibula (22.8%), radius (13.6%), ulna (13.1%) and humerus (13.1%). We believe that the pattern of traumatic fractures among children is partly explained by differences in the activity patterns of children.

Children around the world are routinely engaged in paid and unpaid forms of work that are not harmful to them. However, they are classified as child laborers when they are either too young to work or are involved in hazardous activities that may compromise their physical, mental, social or educational development. In China, child labor refers to children or young workers under the age of 16. Among the patients injured by a machine, 30 persons (62.5%) injured during working. Among the patients struck by object, 22 persons (21.8%) injured during working. We presume that the main causes of child labor are high level poverty and lack of access to good education. Among the patients hurt/cut by others, 24 persons (32.4%) were cut by others. We should tighten up law enforcement to crack down on all kinds of violations and protect the children.

#### 4.2. Associated injuries and complications

The frequency of ASOIs in the patients who presented with traumatic open fractures (42.7%) was significantly higher than those in the patients without open fractures (25.2%) but there was no significant difference in the frequency of complications. The most common complication were wound infection

### Table 2

Fractures wounded by machine, hurt/cut by others, struck by object.

| Age groups | 0-6 | 6-12 | 12-18 | Total |
|------------|-----|------|-------|-------|
| Wounded by machine | 10  | 4    | 34    | 48    |
| Male/female | 6/4 | 2/2  | 32/2  | 40/8  |
| Wound environment | |      |      |       |
| Playing/daily life | 10(100%) | 4(100%) | 4(11.8%) | 18(37.5%) |
| Working       | 0   | 0    | 30(68.2%) | 30(62.5%) |
| Struck by object | 18  | 40   | 43    | 101   |
| Male/female | 14/4 | 33/7 | 41/2  | 88/13 |
| Wound environment | |      |      |       |
| Playing/daily life | 18(100%) | 40(100%) | 21(48.8%) | 79(78.2%) |
| Working       | 0   | 0    | 22(51.2%) | 22(21.8%) |
| Hurt/cut by others | 1   | 11   | 62    | 74    |
| Male/female | 0/1 | 10/1 | 58/4  | 68/5  |
| Mechanism | |      |      |       |
| Hurt by others | 1(100%) | 5(45.5%) | 31(50%) | 37(50.0%) |
| Cut by others | 0   | 0    | 8(12.9%) | 13(17.6%) |

### Table 3

Multivariate analysis of risk factors for open fracture.

| Etiologies         | $P$  | OR   | 95% OR Lower | 95% OR Upper |
|--------------------|------|------|--------------|--------------|
| MVCs               | <0.001 | 8.802 | 5.141        | 15.071       |
| Wounded by machine | <0.001 | 64.229 | 30.731       | 134.24       |
| High fall (>2 m)  | <0.001 | 4.670 | 2.455        | 8.885        |
| Struck by object   | <0.001 | 15.345 | 7.763        | 30.333       |
| Hurt/cut by others | <0.001 | 26.757 | 12.598       | 56.829       |
| Others             | 0.289   | 1.819 | 0.601        | 5.503        |
| Low fall (<2 m)    |      |      |              |              |
| LLFs               | <0.001 | 5.970 | 3.196        | 11.150       |
| ULFs               | <0.001 | 5.865 | 3.069        | 11.211       |
| SFs                | 0.997   | 0.000 | 0.000        | –            |
| RSFs               | 0.999   | 0.000 | 0.000        | –            |
| MFs                | <0.001 | 5.414 | 2.657        | 11.030       |
| CFFs               |      |      |              |              |

ASOIs = associated injuries, CFFs = craniofacial fractures, LLFs = lower limb fractures, MFs = multiple fractures, MVCs = motor vehicle collisions, N = nerve injury, RSFs = fractures of rib and sternum, SFs = spinal fractures, ULFs = upper limb fractures, VI = visceral injury.
The frequencies of associated injuries and wound infection in the OF group were significantly higher than those without open fractures. Therefore, it is clear that open fracture was an important associated factor with high frequencies of ASOs and high hospital costs. The similarities and differences between managing open fractures for younger patients and older patients have been investigated in previous studies. Further research may help to identify and take preventive measures to reduce the number of open fractures, treatment costs and patient distress.

### 4.3. Risk factors for traumatic open fracture

Previous study demonstrates the difference between adult and pediatric open fractures in hospitalized road traffic accidents, and showed that adults had a greater risk for open ULFs compared to children, and the adult pedestrian group particularly had a significantly higher risk for open ULFs than the pediatric group. So, open fractures in pediatric group have its specific characteristics. In the current study, multivariate logistic regression analysis indicated that mechanical trauma, being hurt/cut by others, and being struck by an object were independent risk factors for open fracture. Multivariate logistic regression analysis indicated that lower/upper limb fractures and multiple fractures were independent risk factors for open fractures. Therefore, we should maintain and enhance a safe work environment for younger adolescents and provide a safe and comfortable place for children to rest and play to avoid mechanical trauma and being struck by objects. We should also strengthen school-based moral education to effectively prevent crimes such as being hurt/cut by others.

### 4.4. Treatment of traumatic open fracture

Considering the frequent association of open fractures with other potentially life-threatening injuries in children, stabilizing the patient condition is the first priority. Orthopedic evaluation and management should follow after immediate life-threatening conditions of the patient are stabilized. Information about the nature and mechanism of injury is essential for the trauma surgeon to assess the injuries with respect to severity and other associated injuries. The patients in the OF group presented with higher frequency of multiple fractures, associated injuries and wound infection than the patients in the No-OF group. The frequency of surgical treatment for the patients with traumatic open fractures (87.9%) was significantly higher than those without open fractures (72.2%). The hospital stays and fees for surgical treatment for the patients with traumatic open fractures were significantly higher than those without open fractures. In China, medical insurance is mainly managed by the government; most low-income people and disadvantaged people have to pay out of their own pockets because the rate of medical insurance coverage is low. We advocate aggressive initial wound debridement in theater with early definitive combined orthopedic and plastic surgery in order to obtain skeletal stabilization and soft tissue cover, timely and comprehensive orthoplastic care, vacuum assisted dressing, rapid rehabilitation and we should pay much attention to the medical insurance coverage to the nation’s uninsured.

### 5. Limitations

There were many limitations in the current study. First, the retrospective design and small sample size of the study may have led to selection bias. Second, the lack of information about bone mineral density, serum calcium and vitamin D levels are important limitations of this study. Despite these limitations, we believe that the study can be used as guidance for the prevention and treatment of traumatic open fractures in children and adolescents.

### 6. Conclusions

Etiology (especially being injured by a machine or being hurt/cut by others) and the fracture site (including lower limb fractures, upper limb fractures and multiple fractures) were independent risk factors for open fractures. The patients in the OF group presented with higher frequency of multiple fractures, associated injuries, wound infection, surgical treatment, hospital stays and fees then the patients in the No-OF group. This study provides unique information on epidemiological characteristics of open fractures, pertinent both to medical care providers and to health policy makers allocating resources and formulating prevention strategies in the attempt to deal with the burden of family and society, and future prospective long-term multicenter studies are likely to provide answers to the optimal treatment for traumatic open fractures over the next few years.

### Table 4

Treatment for traumatic fractures in children and adolescents.

|                      | OF group          | No-OF group       | χ² or Z  | P       |
|----------------------|-------------------|-------------------|----------|---------|
| Total                | 206               | 2212              |          |         |
| Treatment            |                   |                   |          |         |
| ST                   | 181(87.9)         | 1596(72.2)        | 23.880   | <0.001  |
| CT                   | 25(12.1)          | 616(27.8)         |          |         |
| Complications        |                   |                   |          |         |
| ST                   | 12(6.6)           | 153(9.6)          | 1.687    | 0.194   |
| CT                   | 5(20.0)           | 27(4.4)           |          | <0.001  |
| ICU stays (days)     |                   |                   |          |         |
| ST                   | 1.0(0.0–4.5)      | 1.0(0.0–3.0)      | −0.550   | 0.602   |
| CT                   | 8.0(5.0–13.5)     | 7.0(3.0–13.0)     | −0.431   | 0.667   |
| Hospital stays (days)|                   |                   |          |         |
| ST                   | 17.0(9.0–29.0)    | 11.0(8.0–17.0)    | −5.418   | <0.001  |
| CT                   | 0.0(0.0–1.0)      | 0.0(0.0–1.0)      | −1.150   | 0.250   |
| Hospital fees (CNY)  |                   |                   |          |         |
| ST                   | 33261.4(19864.8–49375.7) | 24017.2(14954.5–42346.1) | −3.163 | 0.002   |
| CT                   | 4812.6(2964.4–8124.0) | 4074.2(1902.3–7691.1) | −1.236 | 0.216   |

CNYs = Chinese yuans, CT = conservative treatment, ICU = intensive care unit, ST = surgical treatment.
Author contributions
Hongwei Wang, Hong Yuan, Lu Liu: Conceptualization, Methodology, Software, Data curation, Validation, Writing - Original draft preparation. Deluo Wu, Lan Ou, Changqing Li: Formal analysis, Visualization, Investigation, Writing - Original draft preparation. Hailong Yu: Supervision, Data curation, Writing - Reviewing and Editing.

References
[1] Jones G, Cooley HM. Symptomatic fracture incidence in those under 50 years of age in southern Tasmania. J Paediatr Child Health. 2002;38:278–83.
[2] Mattila V, Parkkari J, Kannus P, et al. Occurrence and risk factors of unintentional injuries among 12- to 18-year-old Finns—a survey of 8219 adolescents. Eur J Epidemiol. 2004;19:437–44.
[3] Wang H, Zhou Y, Liu J, et al. Traumatic fractures as a result of motor vehicle collisions in children and adolescents. Int Orthop. 2018;42:625–30.
[4] Moon RJ, Harvey NC, Curtis EM, et al. Ethnic and geographic variations in the epidemiology of childhood fractures in the United Kingdom. Bone. 2016;85:9–14.
[5] Curtis EM, van der Velde R, Moon RJ, et al. Epidemiology of fractures in the United Kingdom 1988–2012: variation with age, sex, geography, ethnicity and socioeconomic status. Bone. 2016;87:19–26.
[6] Halawa EF, Barakat A, Rizk HI, et al. Epidemiology of non-fatal injuries among Egyptian children: a community-based cross-sectional survey. BMC Public Health. 2015;15:1248.
[7] Lempesis V, Rosengren BE, Nilsson JA, et al. Time trends in pediatric fracture incidence in Sweden during the period 1950–2006. Acta Orthop. 2017;88:440–5.
[8] Naranje SM, Erali RA, Warner WC Jr, et al. The epidemiology of pediatric fractures presenting to emergency departments in the United States. J Pediatr Orthop. 2016;36:e45–8.
[9] Cheng JC1, Shen WY. Limb fracture pattern in different pediatric age groups: a study of 3,350 children. J Orthop Trauma. 1993;7:15–22.
[10] Buckley SL, Gotschall C, Robertson W Jr, et al. The relationships of skeletal injuries with trauma score, injury severity score, length of hospital stay, hospital charges, and mortality in children admitted to a regional pediatric trauma center. J Pediatr Orthop. 1994;14:449–53.
[11] Rennie L, Court-Brown CM, Mok JY, et al. The epidemiology of fractures in children. Injury. 2007;38:913–22.
[12] Tandon T, Shaik M, Modi N. Paediatric trauma epidemiology in an urban scenario in India. J Orthop Surg (Hong Kong). 2007;15:41–5.
[13] Stewart DG, Kay RM, Skaggs DL. Open fractures in children. Principles of evaluation and management. J Bone Joint Surg Am. 2005;87:2784–98.
[14] Skaggs DL, Friend L, Alman B, et al. The effect of surgical delay on acute infection following 554 open fractures in children. J Bone Joint Surg Am. 2005;87:8–12.
[15] Khadim MF, Emam A, Wright TC, et al. A comparison between the major trauma centre management of complex open lower limb fractures in children and the elderly. Injury. 2019;50:1376–81.
[16] Nandra RS, Wu F, Gaffey A, et al. The management of open tibial fractures in children: a retrospective case series of eight years’ experience of 61 cases at a paediatric specialist centre. Bone Joint J. 2017;99-B:544–33.
[17] Talbot C, Davis N, Majid I, et al. Fractures of the femoral shaft in children: national epidemiology and treatment trends in England following activation of major trauma networks. Bone Joint J. 2018;100-B:109–18.
[18] Young K, Aquilina A, Chesser TJS, et al. Open tibial fractures in major trauma centres: a national prospective cohort study of current practice. Injury. 2019;50:497–502.
[19] Wuarin L, Gonzalez AI, Zingg M, et al. Clinical and radiographic predictors of acute compartment syndrome in the treatment of tibial shaft fractures: a retrospective cohort study. BMC Musculoskelet Disord. 2020;21:25.
[20] Rubin G, Peleg K, Givon A, Rozen N. Upper extremity open fractures in hospitalized road traffic accident patients: adult versus pediatric cases. J Orthop Surg Res. 2017;12:157.
[21] Nandra RS, Wu F, Gaffey A, et al. The management of open tibial fractures in children: a retrospective case series of eight years’ experience of 61 cases at a paediatric specialist centre. Bone Joint J. 2017;99-B:544–53.
[22] Smith JRA, Fox CE, Wright TC, et al. Orthoplastic management of open tibial fractures in children: a consecutive five-year series from a paediatric major trauma centre. Bone Joint J. 2021;103-B:1160–7.
[23] Sagy M, Singh J, Kalia A, et al. Wound healing of open fractures: comparison of vacuum assisted dressing versus traditional dressing. Int J Orthop Trauma Nurs. 2020;36:100722.
[24] Rexiti P, Zhang TC, Batuer C, et al. Orthopedic treatment for open fracture of lower extremities and soft tissue defects in young children and rapid rehabilitation after operation. Phys Sportsmed. 2020;48:161–4.