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ORIGINAL ARTICLE

Characteristics on 621 cases of craniomaxillofacial fractures

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Abstract

Purpose This study examined a single center's experience with regards to etiology and distribution of fractures treated from July 2015 to August 2016 in Shanghai, China.

Methods The medical records of 621 patients with craniomaxillofacial fractures were reviewed. Patient notes and radiographic images were analyzed for detailed injury data. Age, gender, etiology, and site of fracture were examined. Chi-square test was used to analyze the causes of single and multiple fractures. $p < 0.05$ was considered statistically significant.

Results This study included 426 male and 195 female with a male-to-female ratio of 2.18:1, among which 28.3% were between 19 and 29 years ($n = 176$). In all the fracture sites, orbit was most commonly involved ($n = 319$, 51.4%). Traffic accidents ($n = 304$, 49%) were the most common cause of injury in this study, while ground-level falls were the most common cause of injury in children ($n = 19$, 41.3%). The probability of multiple fractures due to falling from height (88.6%, $p < 0.05$) and traffic accidents (73.3%, $p < 0.05$) were significantly higher than that of other injuries. Orbital fractures have the highest surgical rate ($n = 288$, 90.3%).

Conclusion Craniomaxillofacial fractures predominantly occur in young men, due to traffic accidents. Orbit was involved in most cases. Falling from height and traffic accidents is more likely to cause multiple fractures.

Keywords Craniomaxillofacial fractures · Epidemiology · Etiology

Introduction

The incidence of trauma is increasing every year with millions of adults and children suffer severe craniomaxillofacial fractures worldwide. In China, more than 10 million people died of trauma, millions of people injured each year due to traffic accidents, work-related injuries, natural disasters, and other factors [1, 2]. However, age, sex distribution, the cause of injury, and the most commonly fractured bones have been shown to vary by region, which may related to social systems, cultures, and education in different countries.

In the case of age distribution, sport-related injuries are one of the major causes of craniomaxillofacial injury in children [3]. Up to 20% of American pediatric sport-related injuries involve craniomaxillofacial fractures [4–9]. While in adult patients, the main cause of craniomaxillofacial fractures is traffic accidents, ground-level falls, and violence [10]. The main cause of the injury in developed countries is violence, while in developing countries, traffic accidents are the mainstay.

Because of the lacking in the epidemiological data of craniomaxillofacial fractures in China recent years, the purpose of this study was to obtain epidemiological information. Age, sex, cause of injury, and fracture sites were analyzed.

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Methods

A total of 2335 craniomaxillofacial fractures were examined retrospectively in 621 patients treated at Shanghai Ninth People's Hospital from July 2015 to August 2016. The institutional review board of Shanghai Jiao Tong University School of Medicine approved the protocol, survey, and consent forms used. Patients were evaluated according to age, sex, cause of injury, and location of the fractures. Patients with incomplete medical data were not included in the study.

The identified fractures were classified as: orbital fracture, maxillary fracture, zygomatic complex fracture, mandible fracture, frontal bone fracture, nasal fracture, parietal fracture, and temporal bone fracture.

Frontal plate, sphenoid winglets, sphenoid wings, zygomatic complex, maxillary, and naso-ethmoid fractures which involve orbital margin or walls were classified as orbital fractures.

Obtained data were analyzed using SPSS program version 22.0 (SPSS Inc, Chicago, IL, USA). Categorical data were analyzed by Pearson Chi-squared test. A value of 0.05 was used to determine significance.

Results

Age distribution

Between July 2015 and August 2016, a total of 621 patients with craniomaxillofacial fractures were hospitalized. 426 patients were male with an average age at 34.8 ± 15.3 years; the rest 195 patients were female with an average age at 34.7 ± 16.0 years. The male-to-female ratio was 2.18:1. Age distribution was from 15 months to 84 years. Most cases occurred in patients from 19 to 29 years ($n = 176$, 28.3%), followed by 30–39 year age group ($n = 131$, 21.1%). The underage group (≤ 18 years) had 82 cases (13.2%), among which 46 cases (7.4%) were children (≤ 14 years) (Fig. 1).

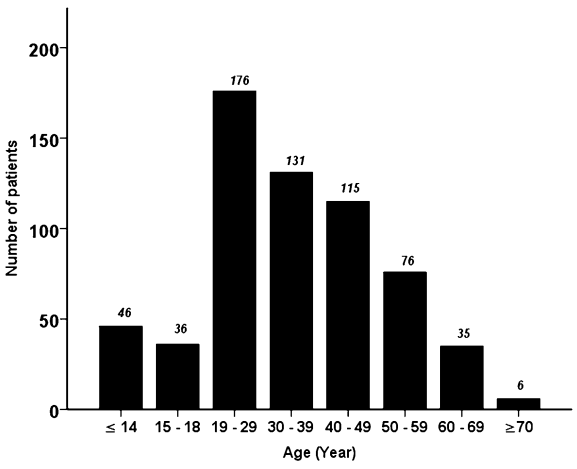

Fig. 1 Age distribution The age distribution of 621 patients with craniomaxillofacial fractures admitted to the Ninth People's Hospital from July 1, 2015 to August 31, 2016

Site distribution of craniomaxillofacial fractures

A total of 2355 fracture lines were found in 621 patients, with an average of 3.79 fractures per case. Orbital fractures were involved in 319 cases, accounting for 51.4% in all patients, followed by zygomatic complex (47%), mandible (39.8%), maxilla (36.9%), nasal bone (18.8%), frontal bone (11.1%), temporal bone (8.7%), skull base (4.7%), and parietal bone (1.1%) (Fig. 2).

The medial orbital wall was the most frequently involved in orbital fracture (38.3%), followed by the orbital floor (28.8%) (Table 1). In mid-face, zygomatic complex was the most vulnerable, accounting for 25.8% of mid-facial fracture, followed by the anterior wall of maxillary sinus (15.8%) (Table 2). The most common fracture of the

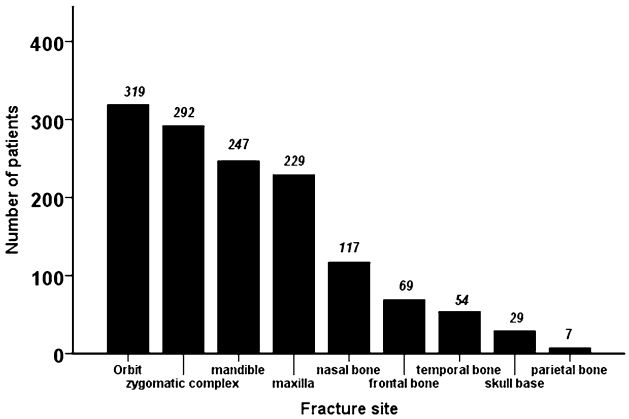

Fig. 2 Fracture site distribution The fracture site was sorted according to the number of patients involved. Orbit was most commonly involved. Parietal bone fracture was the most rare

Table 1 Site distribution of orbital fractures

Fracture site	*n*	%
Orbital floor	187	28.8
Medial orbital wall	248	38.3
Orbital roof	42	6.5
Lateral orbital wall	164	25.3
Optic canal	7	1.1
Total	648	100

The medial orbital wall and the orbital floor are easily fractured, and the orbital roof and lateral orbital walls are stronger

Table 2 Site distribution of mid-facial fractures

Fracture site	*n*	%
Frontal bone	69	6.1
Frontal process of maxilla	56	4.9
Zygomatic body	102	9.0
Zygomatic arch	190	16.8
Maxillary sinus		
Anterior wall	179	15.8
Medial wall	82	7.2
Posterior wall	157	13.6
Floor	69	6.1
Alveolar process of maxilla	46	4.1
Total	1133	100

A total of 1133 fracture lines were found in mid-face area. Most of the fracture lines located in the zygomatic arch and the maxillary sinus

Table 3 Site distribution of mandibular fractures

Fracture site	*n*	%
Symphysis	128	30.2
Body	79	18.6
Ramus	25	5.9
Condylar	134	31.6
Alveolar bone	19	4.5
Angle	33	5.3
Coronoid process	6	1.4
Total	424	100

A total of 424 fracture lines were found in mandible. Most of the fracture lines located in the symphysis and condyle

mandible was condylar fracture (31.6%), followed by the symphysis (30.2%) (Table 3).

Etiology according to age

Traffic accident was the most common cause of injury ($n = 304$, 49%), followed by ground-level falls ($n = 131$, 21.1%) (Fig. 3). The most common etiologies of injury in children were ground-level fall, accounting for 41.3% of the causes in pediatric injuries (Table 4). Detailed information on etiology distribution according to age was as follows (Tables 4, 5, 6, 7, 8, 9, 10).

Quantity of fractures according to etiology

Multiple fractures were observed in 88.6% of the patients who fall from height. This proportion was statistically higher than traffic accident (77.3%, $p < 0.05$), ground-level falls (62.6%, $p < 0.05$), violence (65.7%, $p < 0.05$), and work-related injuries (68.6%, $p < 0.05$). The proportion of multiple fractures in patients caused by traffic accidents is statistically higher than ground-level falls ($p < 0.05$) (Table 11).

Treatment of fracture

Orbital fractures have the highest surgical rate. Of all the 319 patients with orbital fractures, 155 received orbital open reduction and internal fixation (ORIF), 133 received maxillofacial ORIF due to serious combined maxillofacial fractures, and 31 received conservative treatment. The operative rate of orbital fracture was 90.3%. The surgical rate of different fractures is shown in Fig. 4.

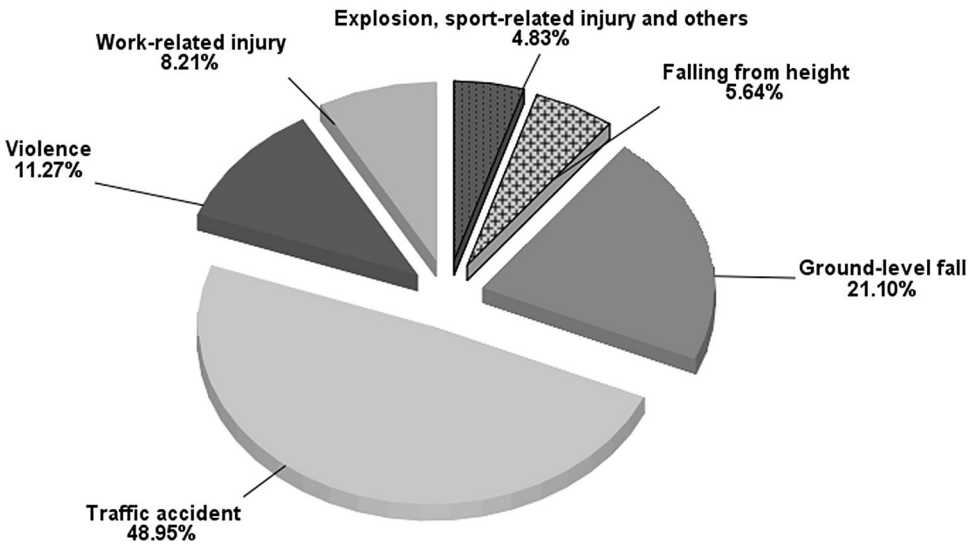

Fig. 3 Etiology distribution of 621 craniomaxillofacial fractures Etiology was classified as traffic accidents, violence, work-related injuries, ground-level falls, falling from heights, explosion, sport-related injuries, and others

Table 4 Etiology distribution in children (≤ 14 years) 46 patients were identified below 14 years

Etiology	*n*	%
Ground-level fall	19	41.3
Violence	2	4.3
Falling from height	7	15.2
Work-related injury	0	0
Traffic accident	16	34.8
Others	2	4.3
Total	46	100

41.3% of the pediatric patients were injured by ground-level falls. 34.8% were injured by traffic accidents

Table 5 Etiology distribution in teenagers (15–18 years) 36 patients were identified between 15 and 18 years

Etiology	*n*	%
Ground-level fall	7	19.4
Violence	5	13.9
Falling from height	2	5.6
Work-related injury	0	0
Traffic accident	17	47.2
Others	5	13.9
Total	36	100

47.2% of the them were injured by traffic accidents. 19.4% were injured by ground-level falls

Table 6 Etiology distribution in patients between 19 and 29 years 179 patients were identified between 19 and 29 years

Etiology	*n*	%
Ground-level fall	32	17.9
Violence	14	7.8
Falling from height	14	7.8
Work-related injury	15	8.4
Traffic accident	93	52.0
Others	11	6.2
Total	179	100

52.0% of the them were injured by traffic accidents. 17.9% were injured by ground-level falls

Table 7 Etiology distribution in patients between 30 and 39 years 131 patients were identified between 30 and 39 years

Etiology	*n*	%
Ground-level fall	20	15.3
Violence	28	21.4
Falling from height	2	1.5
Work-related injury	8	6.1
Traffic accident	65	49.6
Others	8	6.1
Total	131	100

49.6% of the them were injured by traffic accidents. 21.4% were injured due to violence

Table 8 Etiology distribution in patients between 40 and 49 years 115 patients were identified between 40 and 49 years

Etiology	*n*	%
Ground-level fall	29	25.2
Violence	15	13.0
Falling from height	5	4.3
Work-related injury	10	8.7
Traffic accident	52	45.2
Others	4	3.5
Total	115	100

45.2% of the them were injured by traffic accidents. 25.2% were injured by ground-level falls

Table 9 Etiology distribution in patients between 50 and 59 years 74 patients were identified between 50 and 59 years

Etiology	*n*	%
Ground-level fall	11	14.9
Violence	6	8.1
Falling from height	3	4.1
Work-related injury	15	20.3
Traffic accident	39	52.7
Others	0	0
Total	74	100

52.7% of the them were injured by traffic accidents. 20.3% were injured due to work-related injury

Discussion

To the best of our knowledge, the relationship between multiple fractures and the cause of injuries, separate analysis of orbital fractures, were first described in the present retrospective analysis of 621 cases. Due to serious facial, functional, and psychological damage of craniomaxillofacial trauma, the epidemiological investigation of craniomaxillofacial fractures has attracted much attention in the world. Yet, statistics show that the results of surveys vary greatly by geographic region and socioeconomic differences [2]. The variability of prevalence is mainly reflected in some risk factors, such as gender, age, ethnicity, and etiology of injury [11].

All patients surveyed were from Shanghai No. 9 People's Hospital, a large clinical center for craniomaxillofacial injuries, receiving patients from all over China. Therefore, we consider the patients to be representative. High-risk age was 19–29 years, and young adults were the most vulnerable. In 2014, an epidemiological investigation conducted in Beijing, China revealed that the highest risk age for patients with

Table 10 Etiology distribution in elderly patients (≥60 years) 40 patients were identified at least 60 years

Etiology	*n*	%
Ground-level fall	13	32.5
Violence	0	0
Falling from height	2	5.0
Work-related injury	3	7.5
Traffic accident	22	55.0
Others	0	0
Total	40	100

55.0% of the them were injured by traffic accidents. 32.5% were injured by ground-level falls

Table 11 Quantity of fractures according to etiology

Etiology	Single fracture	Multiple fractures	Total
Ground-level fall*△	49 (37.4%)	82 (62.6%)	131 (100%)
Violence*	24 (34.3%)	46 (65.7%)	70 (100%)
Falling from height△	4 (11.4%)	31 (88.6%)	35 (100%)
Work-related injury*	16 (31.4%)	35 (68.6%)	51 (100%)
Traffic accident*	81 (26.7%)	223 (73.3%)	304 (100%)
Others	9 (30.0%)	21 (70.0%)	30 (100%)
Total	183 (29.5%)	438 (70.5%)	621 (100%)

* Compared with falling from height, $p < 0.05$

△Compared with traffic accident, $p < 0.05$

craniomaxillofacial fractures in 2008–2013 was 20–29 years [12]. Epidemiological study of Stomatological Hospital of Wuhan University in 2000–2009 also found that the high-risk age group was 21–30 years [13], which is basically consistent with our study.

In this study, the ratio of male to female was 2.18:1, which was consistent with the related literatures worldwide (2:1–32:1) [14]. In China, this ratio is 2:1–5:1 [12, 15–17]. Men generally account for a larger proportion, probably because men are more involved in physical activity and high-risk occupations than women, while women drive less than men and are less exposed to violence and other factors. However, in the past few decades, the proportion of female injuries has been on the rise. An epidemiological study of craniofacial injuries in Nigeria by Fasola et al. [18] showed that the male-to-female ratio decreased from 6.4:1 (1978–1982) to 3.3:1 (1995–1999). This ratio in China's Xi'an region also dropped from 6:1 (1986–1995) [19] to 3.95:1 (2003) [20] and 2.80:1 in 2008–2011 [21]. This ratio in Shanghai and its surrounding areas also declined from 3.24:1 (2005–2006) [22] to 2.18:1 (2015–2016) (Table 12). The ratio between men and women is gradually decreasing, mainly because of the change of social environment in the past few decades, the opportunities for women to participate in social activities have increased, and the proportion of female trauma has increased.

This study showed that orbital fractures accounted for 51.4% of all craniofacial fractures. The vulnerability of orbit is mainly caused by thin orbital walls and weak resistance to external forces. This study showed that the medial orbital wall was most vulnerable to injury, which is consistent with the results of Cagatay et al. [23]. The cause of this

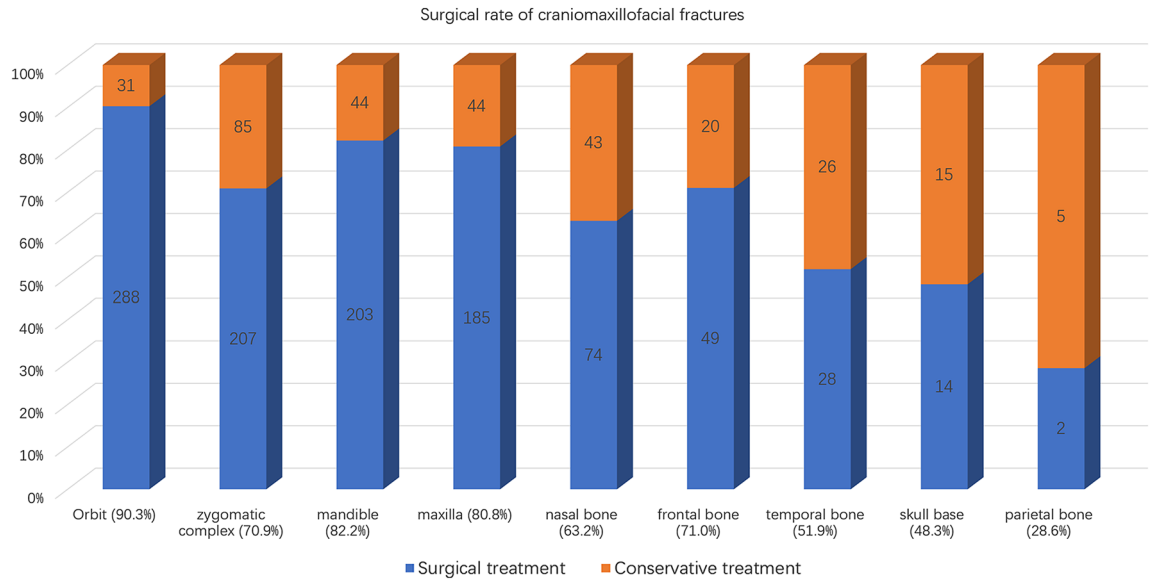

Fig. 4 Surgical rate of craniomaxillofacial fractures

Table 12 Male-to-female ratio

	Study period	M to F ratio	Region
Present study	2015–2016	2.18:1	China
Yang et al. [17]	2010–2013	1.89:1 (infants and preschools only)	China
Chen et al. [12]	2008–2013	2.94:1	China
Chen et al. [21]	2008–2011	2.80:1	China
Mijiti et al. [16]	2006–2010	4.90:1	China
Shi et al. [22]	2005–2006	3.24:1	China
Zhou et al. [15]	2000–2009	4.10:1	China
Li et al. [20]	1996–2002	3.95:1	China
Bo et al. [19]	1986–1995	4.30:1	China
Fasola et al. [18]	1978–1982	6.40:1	Nigeria
	1995–1999	3.30:1	Nigeria

The decrease trend of male-to-female ratio of maxillofacial fractures is obvious in the same region

phenomenon is related to the anatomical structure of the orbit. The medial orbital wall is mainly composed of lamina papyracea, the thickness of which is only 0.2–0.4 mm. Orbital floor is also easy to damage. The posterior of orbital floor is a thin area. Orbital floor fractures occur mostly in this region. The orbital roof and lateral orbital wall are stronger, and less involved in all kinds of trauma; for the thinnest region of lateral orbital wall more than 1 mm, the orbital roof is thickest, mostly composed of frontal plate.

The zygomatic complex is the most frequently involved in mid-facial fracture, which is consistent with current literature [24–26]. Zygomatic complex is the most prominent part in mid-face and is more likely to suffer from fractures. LeFort fractures are most commonly used to classify mid-facial fractures, but typical LeFort fractures are rare because of the specific stress status of the injuries.

Mandibular fractures showed a prevalence of the occurrence in the symphysis and condyle. Other common fracture sites of the mandibular fractures included the mandibular body and angle, which are anatomically weak points of the mandible, and such points are easily fractured by external forces. Because of the high incidence of mandibular fractures and the diversity of traumatic forces, the clinically prevalent sites of mandibular fractures are basically consistent with the theoretical weak points. Mandibular fractures usually result from high-energy attacks to the front of the face, and the symphysis is one of the prominent and weak points of the mandible, and it fractures easily when attacked by direct forces.

The causes of injury and the magnitude, speed, location, and direction of external forces will form corresponding fracture locations, which will lead to greater differences in fracture incidence. In our study, we found that basicranial fracture rarely occurs in patients with lateral orbital wall fracture, zygomatic fracture, and the orbital floor fracture. The possible reason is that the stress conduction interruption of the lateral orbital wall to the frontal bone occurred after zygomatic or orbital fracture, which may absorb impact kinetic energy. Due to the meager bone of orbital floor, impact energy may be absorbed even more when comminuted fracture of orbital floor occurred. Further biomechanical testing will be needed to validate this hypothesis.

In this study, the etiology of injury was classified as ground-level fall, violence, falling from height, work-related injuries, traffic accident, explosion, sport-related injury, and others. Statistical analysis showed that traffic accidents accounted for the most (49%), followed by ground-level falls (21.1%) and violence (11.3%). With the number of cars increasing every year, traffic accidents are becoming more frequent in China. As road safety awareness and road conditions vary from different regions, the previous data showed that 30–60% craniomaxillofacial fractures were caused by traffic accidents [12, 21, 22]. In some developed countries, traffic accidents are no longer the primary cause of injury due to the improvement of laws and safety awareness. Violence and ground-level falls are the major causes of injury in these countries [14].

Accounting for 7.4% in this study, pediatric patients, however, were different from other age groups. Ground-level falls (41.3%) were the primary cause of injury, followed by traffic accidents (34.8%) and falling from height (15.2%). This is mainly because children's access to vehicles, hyperactivity, temperament, and self-control are significantly different from those of adults.

High risk of multiple fractures was observed in falling from height and traffic accidents. Falling injuries were the most serious injuries in this study. Construction workers and high-altitude workers have become the major victims of falling injuries in recent years. Besides, depressed patients, drunk people, and children are also the main group of people suffering from falling. High momentum and high kinetic energy collisions are the main causes of multiple fractures in such injuries which are often accompanied by systemic damage.

Fractures of the orbit are common and challenging to manage. Following the diagnosis of an orbital fracture (and the ocular examination), the initial management is to prevent further injury to the globe while determining if surgical intervention is indicated [27]. The oculocardiac reflex may be induced by orbital fractures due to entrapment of the extraocular muscles, especially in trapdoor fractures. The oculocardiac reflex can cause pronounced bradycardia, vomiting, syncope, and even asystole [28]. In this case, urgent surgery is necessary to release the incarcerated tissues and relieve the stimulus. Indications for elective surgery are enophthalmos (> 2 mm), ocular motility dysfunction, persistent diplopia, CT findings of ocular muscle impingement and

over 50% of floor involvement [27, 29–31]. In the absence of indications for immediate repair, the best timing of surgery is after the reducing of edema, and before bone malunion. Deferring surgery until periorbital edema decreases affords greater exposure and mitigates risk of compartment syndrome. A 2-week window for repair has been supported in the literature [27, 29, 30, 32]. Yet, due to many uncontrollable factors, it is difficult for every patient to have surgery within 2 weeks after injury.

Conclusions

Craniomaxillofacial fractures occur mostly in young men. Ground-level falls are the major cause of craniomaxillofacial fractures in children and elderly people, while other age groups are mainly caused by traffic accidents. Orbital fractures were involved in most cases. High risk of multiple fractures was observed in falling from height and traffic accidents. Further study will be needed to examine combined injuries and management.

Author contributions All authors contributed to study conception and design, data analysis, and drafting the manuscript. All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest Yang Lu and Hangqi Shen are the co-first authors. Yang Lu, Hangqi Shen, Jiayi Wang, and Xiaofeng Lu declare that they have no conflict of interest.

Statement of human rights The study was approved by the School of medicine ethics Committee, Shanghai Jiao Tong University. It was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent For this type of study, formal consent is not required.

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