



## Original article

# Treating fractures in upper limb gunshot injuries: The Cape Town experience



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## ABSTRACT

**Background:** Upper extremity gunshot fractures are generally treated conservatively or surgically using open reduction and internal fixation (ORIF), intramedullary nails (IM) or external fixators. However, there is no gold standard for the management of these complex, multi-fragmentary upper extremity fractures. The aim was to describe and identify the injury patterns, management, complications and associated risk factors for upper extremity gunshot fractures.

**Patient and methods:** Data of patients with upper extremity gunshot injuries that presented to a Level I Trauma Unit in Cape Town, South Africa was collected prospectively over a ten-month period from June 2014 to April 2015. Clinical notes and radiographs were reviewed retrospectively.

**Results:** Fifty-one of 90 patients (56.7%) with ballistic injuries had fractures, 30% had neurovascular injuries and 75% had additional injuries to other anatomical structures including head, neck, spine, chest, abdomen, pelvis and urogenital tract. Most fractures were diaphyseal, multi-fragmentary and extra-articular. Fractures were treated conservatively in more than half of the cases. Median fracture length was 5.5 centimetres. A longer fracture zone was statistically associated with surgical treatment. When surgically treated, open reduction and internal fixation was most often performed. Median hospital stay was six days. Infection and injury severity prolonged hospital stay.

**Discussion:** In contrast to studies from the USA and Europe, most fractures in this study were managed conservatively. High quality prospective controlled trials are required to evaluate radiographic and clinical outcomes of treatment methods for upper extremity gunshot injuries.

**Level of evidence:** IV, case series.

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## 1. Introduction

Orthopaedic trauma services worldwide face an increasing burden of admissions as a result of penetrating trauma including stab wounds and gunshot injuries [1–5]. In developing and resource-limited countries, firearm injury rates are three times more frequent compared with the United States and Europe, with epicentres of interpersonal gunshot violence burden located in Central and South America and Southern Africa [4,5]. Without adequate trauma management, ballistic trauma patients may face life long morbidity. Upper extremity ballistic injuries are common with intra-articular fractures resulting in more severe impact on morbidity [6–10].

Fractures in upper extremity gunshot injuries are generally treated either conservatively using plaster or splint, or surgically with open reduction internal fixation (ORIF) using screws and plates, intramedullary nails (IMN) or external fixators. Wounds can be debrided and the bullet may or may not be removed. The complexity of the fractures, the inconsistency of classification systems outcomes and the wide variety of treatment modalities increase the need for experience-based medicine. There is currently no gold standard for the management of complex, often multi-fragmentary upper extremity fractures caused by gunshot trauma available in literature [6,10–12]. There is no accumulated evidence, no systematic reviews, clinical trials or case-control series focusing on gunshot-induced upper limb fractures. Multiple systematic reviews on non-traumatic humerus fractures reported contrasting conclusions and agreed on the fact that there is insufficient evidence available to decide which management options are best for different types of humerus fractures [13,14]. Surgical intervention for was not superior to conservative management in

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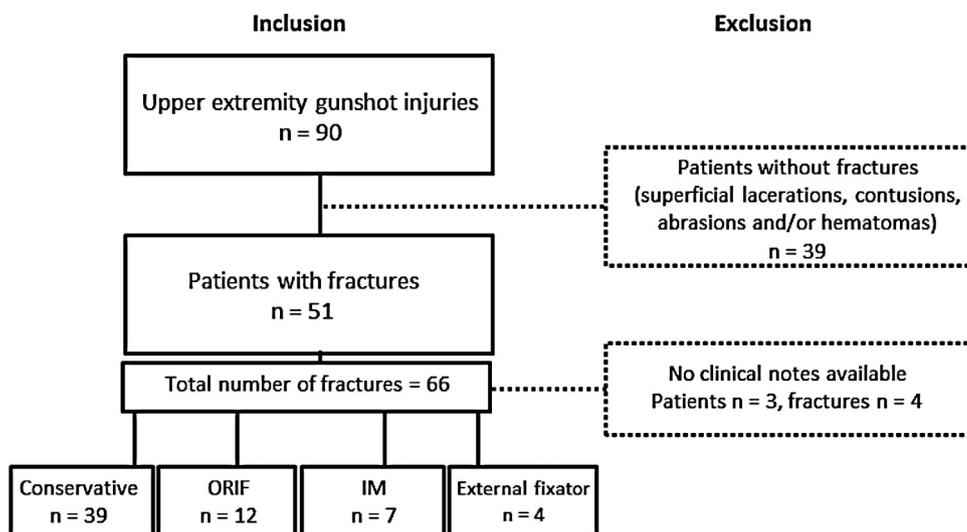


Fig. 1. Flowchart of study population.

upper extremity fractures in Cochrane reviews [13,14]. There is also no conclusive evidence available for forearm fractures.

Moreover, no previous prospective study evaluated the injury patterns and clinical characteristics of fractures in gunshot injuries of the upper extremity. The few studies on gunshots of the upper limb are dated, retrospective case series of small sample sizes from developed countries [6–9,11,15,16] and no evidence is available to guide the management of these injuries in developing countries.

The aim of this study was therefore to identify the injury patterns and clinical characteristics of 90 consecutive patients with fractures of the upper extremity due to gunshot injuries. The objectives are to describe associated injuries and their management, as well as complications and their possible risk factors.

## 2. Patients and methods

### 2.1. Study design

This is a retrospective cohort study of all patients with fractures of the upper extremity due to gunshot injuries who presented to the Trauma Unit at Groote Schuur Hospital in Cape Town over a 10-month period between July 2015 and April 2016.

## 3. Methods

Patients with upper extremity gunshot injuries were selected from the electronic Trauma Health Record, a prospectively maintained electronic registry of all patients presenting to our Trauma Unit. Additional information regarding the injury, treatment and in-hospital characteristics was reviewed retrospectively through clinical notes and radiographs.

### 3.1. Patients

All patients with ballistic injuries to the upper extremity who presented between June 2014 and March 2015 were included. We defined upper extremity as involvement of clavicle, scapula, humerus, radius and ulna. Patients with isolated fractures of the skull, face, ribs, hands, fingers and lower extremities were excluded. Patients without fractures were excluded from further analysis as

bony injuries were the specific focus of this paper. Patients with insufficient data available were also excluded.

### 3.2. Methods of assessment

Patient demographics including age, gender, location and employment status were collected. The variables used for injury classification were number of fractures, nerve injuries, arterial injuries and associated injuries. The Arbeitsgemeinschaft für Osteosynthesefragen and Orthopaedic Trauma Association (AO/OTA) Fracture and Dislocation Classification was used to classify fractures. The treatment strategy was documented as conservative, ORIF, IMN, and external fixation. Union and time to union were assessed. Radiographic union was assessed by a radiologist and two upper extremity specialist surgeons. It was defined as at least three cortices bridged by callus on lateral and AP radiographs.

To assess complications, reoperations, secondary infections and mortality we reported on a time scale since hospital admission (more or less than 30 days). Reoperations were defined as planned (for example in the management of open fractures) and unplanned procedures, which were not anticipated during the initial management plan. The total period of follow-up and the number lost to follow-up were also assessed.

### 3.3. Statistical analysis

Demographic and clinical data of the patients were compared using bivariate analysis. The  $p$ -values were determined by the Chi<sup>2</sup> or two-sided Fisher's exact test for categorical variables, and by the Student's  $t$ -test or the Mann–Whitney  $U$  test for continuous variables. Z-tests were used test for significant differences between two population proportions. Significant confounders ( $p < 0.05$ ) between the compared groups were identified using multivariate analysis. Risk factors identified by bivariate analysis at  $p < 0.2$  were put into a multivariate regression model to test for (independent) association between variables. Univariate and multivariate analyses were performed to investigate associations between age, Injury Severity Score, associated injuries, other injuries, hospital stay and complications. Values were reported as percentages for categorical variables and mean  $\pm$  SD or median, range and interquartile range for continuous variables. Analyses

were performed using SPSS version 23 (Statistical Package for the Social Sciences, IBM Company, New York).

## 4. Results

### 4.1. Demographics

Of 90 consecutive patients with upper limb gunshot injuries, 51 (56.7%) had fractures and were eligible for inclusion. These patients had a median age of 28 years (range: 15.2–55.1; IQR: 9.0). Thirty-nine (43.3%) patients without fractures had superficial lacerations, contusions, abrasions and/or haematomas (Fig. 1). Out of 51 patients with upper extremity fractures, 41 patients had one fracture (80.4%), seven patients had two fractures (13.7%), one patient had 3 fractures (5.8%), and two patients had 4 fractures (3.7%). This resulted in a total of 66 fractures in 51 patients. Ninety-six per cent were male ( $n = 49$  of 51), 78.4% were unemployed ( $n = 40$  of 51) and 68.9% were referred from informal housing townships in the Cape Flats ( $n = 31$ ). On admission to the Trauma Unit, the Injury Severity Score (ISS) for patients with fractures was of 9.0 (range: 1–59; IQR: 10.0).

### 4.2. Injury pattern

Fractures included 5 (7.6%) clavicle, 7 (10.6%) scapula, 23 (34.8%) humerus, 16 (24.2%) radius and 15 (22.7%) ulna (total 66). Most fractures were multi-fragmentary ( $n = 57$ , 86.3%); 7 fractures (10.6%) contained more than ten fragments. All clavicular fractures were extra-articular and most were multi-fragmentary ( $n = 4$ ; 80%). Scapular fractures involved the body ( $n = 4$ ) or acromion ( $n = 2$ ); one patient had extensive injuries to the scapula and glenoid due to a complete articular fracture combined with a multi-fragmentary fracture of the neck of the scapula. The anatomic distribution of the 54 long bone fractures is displayed in Table 1. Most fractures were diaphyseal ( $n = 34$ ; 51.5%) and only 9.1% were partial or complete articular fractures ( $n = 6$ ). Six patients had ipsilateral radius and ulna fractures; other forearm fractures were isolated.

Neurovascular injuries were documented in 22 (43.1%) patients. Seventeen patients (23.5%) had a fallout of the ulnar nerve ( $n = 7$ ), median nerve ( $n = 5$ ), radial nerve ( $n = 3$ ) and brachial plexus ( $n = 2$ ). Vascular injuries involved the brachial artery ( $n = 3$ ) and axillary artery ( $n = 2$ ). Thirty-six patients (70.6%) suffered injuries to other anatomical structures including head, neck, spine, chest, abdomen, pelvis and urogenital tract.

### 4.3. Management

Thirty-nine (59.1%) fractures were treated conservatively with plaster or splinting, local wound care and dressings, antibiotics and early physiotherapy, 4 (6.1%) fractures were treated with external fixators, 12 fractures (18.2%) were treated with open reduction internal fixation techniques (ORIF), and in 7 fractures (10.6%) an intramedullary nail (IM) was done. Clavicle fractures were treated conservatively except for one patient with an extra-articular fracture of the lateral clavicle, which was treated with ORIF. Six of the 7 scapular fractures were treated conservatively and one patient with a multi-fragmentary fracture of the body was treated with ORIF. The management of humerus, radius and ulna fractures is displayed in the pie charts in Fig. 2. Most humerus and ulna fractures were treated conservatively, whilst most radius fractures were managed surgically ( $p < 0.03$ ). Patients with other injuries were treated conservatively in 60.0% of the cases ( $n = 21/35$ ).

**Table 1**

Distribution of long bone fractures according to AO/OTA Classification. Type of fracture in X-ray example in italics.

X-ray example	Bone	Fractures (n; %)
	Humerus	23
	Articular	3 (13.0%)
	Multi-fragmentary	21 (91.3%)
	Proximal (n each)	3 (13.0%)
	11-A3	3
	Diaphysis (n each)	17 (73.9%)
	12-A1	1
	12-B3	2
	12-C3	14
	Distal (n each)	3 (13.0%)
	13-B2.1	1
	13-C3	2
	Radius	16
	Articular	1 (6.3%)
	Multi-fragmentary	12 (75.0%)
	Proximal (n each)	3 (18.6%)
	21-C2, 21-A3.3, 21-A2.1	1
	Diaphysis (n each)	10 (62.5%)
	22-A2.2, 22-C3.3	2
	22-B2.2	6
	Distal (n each)	3 (18.6%)
	23-A3	3
	Ulna	15
	Articular	2 (13.3%)
	Multi-fragmentary	13 (86.7%)
	Proximal (n each)	4 (26.7%)
	21-A1.1, 21-A3.3, 21-B1, 21-C2	1
	Diaphysis (n each)	7 (46.7%)
	22-B1.2	5
	22-C3.3	2
	Distal (n each)	4 (26.7%)
	23-A1.3	3
	23-A3	1

### 4.4. Complications

Complications were defined as reoperations, secondary infections and death. Five patients (9.8%) had ten reoperations in total. There were two cases of unplanned surgeries due to surgical site sepsis. Planned reoperations included re-looks, adjustments and

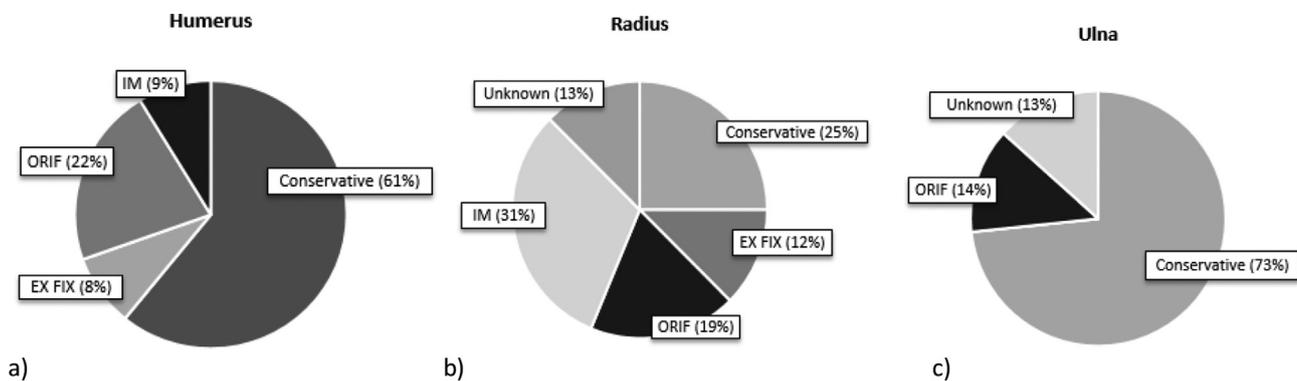


Fig. 2. Management strategies in upper limb fractures: a: humerus; b: radius; c: ulna.

removal of external fixators ( $n=6$ ) and intramedullary nailing ( $n=2$ ). Six cases of secondary infections were seen in 51 patients (11.8%). These patients all had complex, multi-fragmentary fractures. Two of these patients were treated conservatively, two had external fixators, one was treated using ORIF and one using IM. Their injury pattern or antibiotic regime was not different from non-septic patients in the study group. The infection occurred within 30 days post-injury ( $n=5$ ) and concerned surgical wound sepsis ( $n=3$ ). There were only two cases of external fixation pin site sepsis. All patients survived.

#### 4.5. Hospital stay

The median hospital stay was 6 days ranging from 0 to 53 (IQR: 12.5). Treatment strategy, infection and Injury Severity Score are associated with a longer hospital stay in univariate and multivariate analysis ( $p < 0.001$ ) with respective coefficients 0.28, 0.53 and 0.41. Union had occurred at a median of 80 days post-injury (range: 43–145 days; IQR: 48.5). The follow-up rate defined as more than 16 weeks post-injury for patients with fractures was 45.1% ( $n=23$ ). Thirty-five patients could not be followed up (68.6%), 3 could be followed until 4 weeks post-injury, 4 were followed up until 6 weeks and 1 was followed up until 8 weeks post-injury.

## 5. Discussion

### 5.1. Main findings

Most of the 51 patients with fractures, had complex injury patterns and were treated conservatively. This management strategy resulted in an overall sepsis rate of 10%, a median hospital of 6 days and a median time to union of 80 days, no deaths and two unplanned reoperations.

### 5.2. Demographics

The majority of patients were referred from informal housing townships in the Cape Flats, known for its high rates of gangsterism, drug violence and other sorts of intended and interpersonal violence. Violence and homicide studies from other low and middle-income countries have reported similar demographics including young male patients with easy availability to firearms [17]. Moreover, the patients living in informal settlements face severe financial restraints including a lack of transport money for follow-up and low resources regarding postoperative care such as physiotherapy strongly affect the outcomes of our management.

### 5.3. Injury pattern

More than half of the patients with gunshot injuries to the upper extremity had at least one fracture. As demonstrated in Table 1, most fractures were complex, irregular and multi-fragmentary with a large fracture length. Most other studies have reported on a similar pattern but comparison is often challenging as various systems to classify are used such as injury location, bullet velocity, Gustilo-Anderson classification, damage to soft tissue or purely a description of the injury [7,8,10,15,16].

### 5.4. Management strategies

Ball et al. earlier emphasized that thorough physical examination remains the mainstay in the work-up of penetrating extremity trauma suspect for neurovascular or soft tissue injuries [18] (Fig. 2). Proximal occlusion using compression or tourniquet is the strategy of choice for the rapid management of hemorrhagic wounds. Many Western trauma centres treat gunshot related fractures with external fixation [19,20] or promote a thorough surgical debridement and internal fixation [6,10,21–23]. In our series, upper extremity fractures were treated conservatively in more than half of the cases with minimal incidence of sepsis or nonunion. Fractures of the clavicle, scapula, humerus and ulna were treated mostly conservatively, while most radius fractures were treated surgically. Due to the effect on pronation and supination the radius has a much smaller acceptable limit of rotational and axial malunion which might have triggered fixation in a significantly larger number of cases.

Overall, this supports conservative management as treatment option in low resource settings, even for complex fracture patterns and is in line with recommendations from recent meta-analyses in the treatment of proximal humerus, humeral shaft and ulna fractures in blunt injuries [24–27]. To date it is unclear whether surgical treatment of proximal humerus and humerus shaft fractures results in better clinical outcomes [27,28]. The indication for wound debridement or exploration in our cohort was given when wound contamination, associated neurovascular injuries and large soft tissue damage were evident. This has been suggested in previous studies [29,30]. Literature provides evidence both in favour of and against formal debridement of musculoskeletal injuries [31].

Conservative management is mainly limited to immobilization and home exercises with poor access to physiotherapy in informal settlements. In addition to these challenges patients often spend a day's wage for transport to the hospital which limits follow-up visits. This eliminates complex conservative treatment regimens and makes a simple approach necessary. Without early training

and adequate follow-up, gunshot fractures may lead to malunion or pseudo arthritis with severe stiffness and functional limitations.

### 5.5. Complications

Our cohort showed a high severity of injury and associated nerve injuries in upper limb gunshot wounds is likely due to the proximity of the upper limb to vital organs in the abdomen, chest, head and neck. The high number of neurovascular injuries was consistent with previous research on penetrating extremity trauma. This should raise meticulous awareness amongst physicians in the primary trauma assessment.

The rate of associated injuries was high when compared to European studies [19], but similar to US studies [6,20,21]. The observed infection rate of 11.8% was relatively high when compared with previous reports [17,20–24] but is similar to penetrating fractures treated surgically in low-income settings [32,33]. Previously, a prospective multicentre study on the outcomes of a standardized IM nailing technique between a South African and European trauma centre demonstrated lower complication rates in South Africa. Most of these patients were treated surgically which highlights the importance of non-surgical management if amenable. There were no cases of nonunion.

### 5.6. Strengths and limitations

Most of the literature available in orthopaedic ballistic trauma is over a decade old. Although modern technology and techniques may have changed the way in which developed countries treat such fractures, the available experience should not be regarded obsolete given the high gunshot trauma burden in low resource settings. The strength of our study is a large sample size, as the weekly number of ballistic trauma patients seen at Groote Schuur Hospital generally exceeds the yearly number of ballistic injuries seen at Western trauma centres [4,5,30]. Therefore, experience rather than evidence is crucial in the best management of this specific type of injuries.

We noted a low follow-up rate in our cohort, which is a scientific limitation of this study. This high loss to follow-up is similar to other studies reporting on ballistic trauma patients, especially in endemic areas [19,26,27]. Nonetheless, this follow-up rate is realistic, as illustrated by the fact that up to five percent of our study population had died as a result of another gunshot injury during the study period. With respect to union, patients may have united before their follow-up appointment and the decision on whether there is union or not from radiographs remains subjective and prone to observer bias. We aimed to minimize bias and imprecision by having two independent observers. Furthermore, the time in hospital due to orthopaedic trauma may be over-reported as patients might have been treated for non-orthopaedic injuries in other trauma wards prior or after admission to the orthopaedic wards. This is not displayed in our admission system. With respect to complication rate, poor follow-up, missing data and the small sample size decrease the statistical and clinical power to identify risk factors associated with such events.

## 6. Conclusions

Most upper limb fractures due to gunshot trauma were managed conservatively with low rates of reoperation, death and a sepsis rate of 10%. This strategy suits a setting with limited access to operating facilities or implants. Prospective studies with planned fixed interval follow-up appointment are required to adequately evaluate radiographic and clinical outcomes of upper extremity gunshot injuries.

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## Contribution

Esmee Engelmann: study design, data collection, analysis, write up.

Stephen Roche: clinical notes, assistance in writing and editing.

Sithombo Maqungo: inclusion of patients in database.

Du Preez Naude: reviewing X-rays and clinical notes.

Michael Held: daily supervision, editing final article.

## Disclosure of interest

The authors declare that they have no competing interest.

## References

- [1] Mock C, Cherian M. The global burden of musculoskeletal injuries: challenges and solutions. *Clin Orthop Relat Res* 2008;466:2306–16.
- [2] Fitzharris M, Yu J, Hammond N. Injury in China: a systematic review of injury surveillance studies conducted in Chinese hospital emergency departments. *Br Med J* 2011;26:18–34.
- [3] Bhalla K, Harrison J, Shahraz S, Fingerhut L. Availability and quality of cause-of-death data for estimating the global burden of injuries. *Bull World Health Organ* 2010;88:831C–8C.
- [4] Geneva Declaration Secretariat. Global Burden of Armed Violence 2015. Geneva: Geneva Declaration Secretariat; 2015. <http://www.genevadeclaration.org/measurability/global-burden-of-armed-violence/global-burden-of-armed-violence-2015.html>.
- [5] United Nations Office on Drugs and Crime. <https://www.unodc.org/gsh/en/data.html>.
- [6] Wisniewski TF, Radziejowski MJ. Gunshot fractures of the humeral shaft treated with external fixation. *J Orthop Trauma* 1996;10:273–8.
- [7] Keller A. The management of gunshot fractures of the humerus. *Inj J Care Inj* 1995;26:93–6.
- [8] Mandrella B, Abebaw TH, Hersi ON. The management of gunshot fractures of the humerus shaft with large bone defects under unfavourable conditions. A report of three cases from Ethiopia and Somalia. *Unfallchirurg* 1997;100:154–8.
- [9] Karas EH, Strauss E, Sohail S. Surgical stabilization of humeral shaft fractures due to gunshot wounds. *Orthop Clin North Am* 1995;26:65–73.
- [10] Wilson RH. Gunshots to the hand and upper extremity. *Clin Orthop Relat Res* 2003;408:133–44.
- [11] Balfour GW, Marrero CE. Fracture brace for the treatment of humerus shaft fractures caused by gunshot wounds. *Orthop Clin North Am* 1995;26(1):55–63.
- [12] Mahabier KC, Van Lieshout EM, Bolhuis HW, Bos PK, Bronkhorst MW, et al. HUMeral shaft fractures: measuring recovery after operative versus non-operative treatment (HUMMER): a multicenter comparative observational study. *BMC Musculoskelet Disord* 2014;15:39.
- [13] Bassett R. Proximal and midshaft humerus fractures in adults. UpToDate, last updated 2016.
- [14] Zhao J, Wang J, Huang W, Zhang P. Surgical interventions for treating humeral shaft fractures in adults. *Cochrane Database Syst Rev* 2016 [4, Art No. CD012174].
- [15] Johnson EC, Strauss E. Recent advances in the treatment of gunshot fractures of the humeral shaft. *Clin Orthop Relat Res* 2003;408:126–32.
- [16] Tarkin IS, Hatzidakis A, Hoxie SC, Giangara CE, Knight RQ. Arthroscopic treatment of gunshot wounds to the shoulder. *Arthrosc J Arthrosc Relat Surg* 2003;19:85–9.
- [17] Murray J, Ricardo de Castro Cerqueira D, Kahn C. Crime and violence in Brazil: systematic review of time trends, prevalence rates and risk factors. *Aggress Violent Behav* 2013;18:471–83.
- [18] Ball C. Penetrating nontorso trauma: the extremities. *Can J Surg* 2015;58:286–8.
- [19] Persad IJ, Reddy RS, Saunders MA, Patel J. Gunshot injuries to the extremities: experience of a UK trauma centre. *Inj J Care Inj* 2005;36:407–11.
- [20] Elstrom JA, Pankovich AM, Egwele R. Extra-articular low-velocity gunshot fractures of radius and ulna. *J Bone Joint Surg Am* 1978;60:335–41.
- [21] Lenihan MR, Brien VW, Gellman H, Itamura J, Kuschner SH. Fractures of the forearm resulting from low-velocity gunshot wounds. *J Orthop Trauma* 1992;6:32–5.
- [22] Luce EA, Griffen WO. Shotgun injuries of upper extremity. *J Trauma-Injury Infect Crit Care* 1978;18:487–92.
- [23] Marcus NA, Blair WF, Shuck JM, Omer GE. Low-velocity gunshot wounds to extremities. *J Trauma-Injury Infect Crit Care* 1980;20:1061–4.
- [24] Hahn M, Strauss E, Yang EC. Gunshot wounds to the forearm. *Orthop Clin North Am* 1995;26:85–93.

- [25] Gao Y, Zhang W, Duan X, et al. Surgical interventions for treating radial head fractures in adults. *Cochrane Database Syst Rev* 2013;5:CD008987.
- [26] Handoll HHG, Pearce PK. Interventions for isolated diaphyseal fractures of the ulna in adults. *Cochrane Database Syst Rev* 2004;2:CD000523.
- [27] Handoll HHG, Brorson S. Interventions for treating proximal humeral fractures in adults. *Cochrane Database Syst Rev* 2015;(11):CD000434.
- [28] Gosler MW, Testroote M, Morrenhof JW, Janzing HMJ. Surgical versus non-surgical interventions for treating humeral shaft fractures in adults. *Cochrane Database Syst Rev* 2012;1:CD008832.
- [29] Dickey RL, Barnes BC, Kearns RJ, Tullos HS. Efficacy of antibiotics in low-velocity gunshot fractures. *J Orthop Trauma* 1989;3:6–10.
- [30] United Nations General Assembly. Report of the panel of governmental experts on small arms. General and complete disarmament: small arms. New York: United Nations General Assembly; 1997. <http://www.un.org/depts/dda/Firstcom/SGreport52/a52298.html>.
- [31] Sathiyakumar V, Thakore R, Stinner D, Obremskey W, Ficke J, Sethi M. Gunshot-induced fractures of the extremities: a review of antibiotic and debridement practices. *Curr Rev Musculoskelet Med* 2015;8:276–89.
- [32] Gross T, Huettl T, Audigé L, Frey C, Monesi M, Seibert FJ, et al. How comparable is so-called standard fracture fixation with an identical implant? A prospective experience with the antegrade femoral nail in South Africa and Europe. *Injury* 2010;41:388–95.
- [33] Young S, Atle Lie S, Hallan G, Zirkle L, Engesaeter L, Havelin L. Low infection rates after 34,361 intramedullary nail operations in 55 low- and middle-income countries. Validation of the Surgical Implant Generation Network (SIGN) Online Surgical Database. *Acta Orthop* 2011;82:737–43.