

RESEARCH ARTICLE

Characteristic Features and Outcomes of Open Gunshot Fractures of Long-bones with Gustilo Grade 3: A Retrospective Study

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Abstract

Background: The incidence of gunshot injuries is growing, and civilian orthopedics should be more aware of the treatment and consequences of these injuries. This study aimed to describe the characteristic features and complications of gunshot injuries to long-bones.

Methods: A total of 50 patients who presented with an open gunshot fracture of the tibia, humerus, and femur in the emergency room of our hospital were included in this study. Primary irrigation and debridement, as well as prophylactic antibiotics, were administered in the emergency room. The treatment was performed either conservatively (n=4) or surgically (n=46). The external fixator, nailing, or plating was used for surgical fixation.

Results: The mean age and follow-up duration of the patients were 32.3±9.9 years and 13.1±5.6 months, respectively. The most common injured long bone was the femur (32 of 50). Regarding the Gustilo grade, IIIa, IIIb, and IIIc were observed in 37, 7, and 5 patients, respectively. The Masquelet technique was used for 7 (14%) patients, and 12 (24%) cases had skin flaps. Furthermore, the vascular injury was present in 5 (10%) patients, and Malunion of the fracture site was observed in 5 (10%) cases. Nonunion of the fractured bone occurred in 13 (26%) patients that was significantly associated with the presence of vascular injuries ($P=0.02$). Postoperative infection occurred in 9 (18%) patients and was significantly associated with the presence of skin flap ($P=0.014$).

Conclusion: Gunshot injuries of long bones are associated with a high incidence of post-treatment complications, such as infection and nonunion, and therefore, more intensive care should be taken to avoid these complications.

Level of evidence: III

Keywords: Gunshot injury, Gustilo classification, Infection, Nonunion

Introduction

Globally, the incidence of gunshot injuries is growing significantly due to the increasing rate of violence in societies (1). In the United States, the rate of

nonfatal gunshot injuries is reported to be between 60,000 and 80,000 annually (2). Battlefield gunshot injuries are also an enormous problem causing sustained

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conflict in about 70% of cases (3). Management of gunshot injuries can be clinically challenging, as these injuries might involve several structures, such as soft tissues, bone, musculotendinous, arteries, and nerves. Therefore, many resources must be provided to care for each patient, leading to a continuous burden on the community and hospital (4).

In the long bones, the majority of gunshot injuries are associated with comminuted open fractures, posing a therapeutic challenge to orthopedic surgeons. Management of these injuries requires an in-depth understanding of the injury and the nature of low and high energy transfer to the limb infrastructures (5). Once occurred, a wide range of therapeutic options, such as non-operative splintage, external fixation, internal fixation, or intramedullary nailing, are available (5). Even so, several aspects of gunshot treatment remain controversial (6). Comminuted fractures are even more challenging and might get complicated with nonunion or malunion in a considerable number of patients (7).

Due to the increasing rate of gunshot injuries and their challenging treatment, civilian orthopedic surgeons are required to get more familiar with the mechanisms of these injuries, their treatment, and postoperative complications. This study aimed to discuss the characteristic features and post-treatment complications, as well as their predisposing factors in a series of patients with non-battlefield gunshot injuries of the long-bones with Gustilo grade III.

Materials and Methods

This study was approved by the review board of our institute, and patients provided written consent to use their medical data for publication. In a prospective cohort, patients who were presented with a gunshot injury to the emergency department of our hospital between 2015 and 2018 were evaluated. Patients were included if their long bones (tibia, femur, and humerus) were injured and had a follow-up of at least six months. On the other hand, patients who had closed fractures were excluded from the study. Finally, a total of 50 patients were identified as eligible for the study.

In the emergency ward, the patients' care was performed according to the principles of dealing with open fractures, which included primary irrigation and debridement (8). The patients received intravenous antibiotic prophylaxis for at least 24 h with a third-generation cephalosporin. Treatment was conservative in 4 (8%) patients, and surgery was performed in the remaining 46 (92%) cases. Surgical fixation was performed using an external fixator, nailing, or plating.

The Gustilo-Anderson classification system for open fractures was used for typing the fractures. According to this system, the fractures are classified into three grades, including I (clean wound with less than 1 cm in length), II (wound with 1-10 cm in length without large soft-tissue damage, flaps, or avulsions), and III (wound with extensive soft-tissue laceration (more than 10 cm) or tissue loss/damage or an open segmental fracture). Grade III was further subdivided into three subgrades of IIIa (wound with adequate periosteal coverage of

the fractured bone), IIIb (wound with extensive soft-tissue loss, periosteal stripping, and bone damage, generally associated with massive contamination requiring further soft-tissue coverage procedure), and IIIc (wound associated with an arterial injury needing repair) (9).

The patients were visited two weeks after the initial treatment and monthly afterward for up to six months. All the follow-up visits were performed at the treatment institution. In each follow-up visit, the wound appearance was checked, and wound complications were recorded. The union of the fractures was evaluated six months after the injury using the observation of callus formation in the plain radiographs.

Statistical analysis

The data were analyzed in SPSS software (version 16), and the descriptive statistics were presented as mean±SD, number, and percentage. Furthermore, the chi-square or Fisher's exact tests were used for the analysis of qualitative data. A *P*-value of <0.05 was considered statistically significant.

Results

In total, 50 patients with a gunshot injury to long bones were included in this study. The study population consisted of 46 (92%) males and 4 (8%) females. The mean age and follow-up duration of the patients were 32.3±9.9 years and 13.1±5.6 months, respectively. The most common injured long bone was the femur (32 of 50). Treatment was performed conservatively in 4 (8%) and surgically in 46 (92%) patients. Gustilo grade IIIa was the most frequent type of open fracture in this series (37 of 50), and vascular injury was present in 5 (10%) patients only. In total, 12 (24%) patients had skin flaps, and the Masquelet technique was used for 7 (14%) patients. The characteristic features of the patients are demonstrated in more detail in Table 1.

Postoperative infection occurred in 9 (18%) patients, and the Malunion of the fracture site was observed in 5 (10%) cases. Furthermore, nonunion of the fractured bone occurred in 13 (26%) patients, and union of the fractured bone was non-complicated in the remaining 33 (64%) patients.

A significant association was found between the incidence of infection and flap so that the rate of infection was significantly higher in patients who had flaps ($P=0.014$). The rate of infection was not significantly associated with the age and gender of the patients ($P=0.41$ and $P=0.33$, respectively). In addition, the incidence of infection was not significantly associated with the type of treatment, Gustilo grade of fracture, and union status ($P=0.26$, $P=0.16$, and $P=0.22$, respectively). No other significant association was found between the patients' characteristics and the incidence of infection [Table 2]. The incidence of nonunion was associated with the presence of vascular injury so that patients with vascular injury had a higher rate of nonunion ($P=0.02$). Moreover, the incidence of nonunion was not associated with the infection, site of the fracture, and flap. The rate of nonunion in different subgroups of patients with

Table 1. Characteristic features of patients with gunshot injury of long bones

| Variable | Patients (n=50) |
|---------------------|-----------------|
| Age | 32.3 ± 9.9 |
| Gender | |
| Male | 46 (92) |
| Female | 4 (8) |
| Smoking | |
| Yes | 47 (94) |
| No | 3 (6) |
| Involved bone | |
| Humerus | 4 (8) |
| Femur | 32 (64) |
| Tibia | 14 (28) |
| Treatment | |
| Conservative | 4 (8) |
| Nail | 10 (20) |
| Plate | 18 (36) |
| External fixator | 18 (36) |
| Gustilo grade | |
| 3a | 37 (74) |
| 3b | 8 (16) |
| 3c | 5 (10) |
| Vascular injury | |
| Yes | 5 (10) |
| No | 45 (90) |
| Flap | |
| Yes | 12 (24) |
| No | 38 (76) |
| Masquelet technique | |
| Yes | 7 (14) |
| No | 43 (86) |

Data are presented as mean ± SD of number (%)

gunshot injury of the long-bone is demonstrated in detail in Table 3.

Discussion

This study evaluated the outcome of gunshot injuries of long-bones in 50 patients. During the six months follow-up of the patients, 9 (18%) infections, 13 (26%) nonunions, and 5 (10%) malunions of the fractured bone were observed in the present series. A higher incidence of infection was also noted in patients who had a skin flap, and nonunion was more prevalent in patients with vascular injury.

Wiss et al. evaluated the outcome of low-velocity gunshot injury of the femur in 56 patients that were treated with interlocking nailing. The fractures had

Table 2. The incidence of infection in different subgroups of patients with gunshot injury of long-bones

| Variable | Infection (n=9) | P value |
|---------------------|-----------------|---------|
| Age | | |
| <20 years | 0 of 7 (-) | |
| 20-40 years | 7 of 33 (21.2) | 0.41 |
| >40 years | 2 of 10 (20) | |
| Gender | | |
| Male | 9 of 46 (19.6) | 0.33 |
| Female | 0 of 4 (-) | |
| Smoking | | |
| Yes | 9 of 47 (19.1) | 0.54 |
| No | 0 of 3 (-) | |
| Involved bone | | |
| Humerus | 0 of 4 (-) | |
| Femur | 7 of 32 (21.9) | 0.74 |
| Tibia | 2 of 14 (14.3) | |
| Treatment | | |
| Conservative | 2 of 4 (50) | |
| Nail | 1 of 10 (10) | 0.26 |
| Plate | 4 of 18 (22.2) | |
| External fixator | 2 of 18 (11.1) | |
| Gustilo grade | | |
| 3a | 5 of 37 (13.5) | 0.63 |
| 3b | 2 of 8 (25) | |
| 3c | 2 of 5 (40) | |
| Vascular injury | | |
| Yes | 2 of 5 (40) | 0.17 |
| No | 7 of 45 (15.6) | |
| Flap | | |
| Yes | 5 of 12 (41.7) | 0.014* |
| No | 4 of 38 (10.5) | |
| Masquelet Technique | | |
| Yes | 3 of 7 (42.8) | 0.1 |
| No | 6 of 43 (13.9) | |

Data are presented as nominator of denominator (%)

* $P < 0.05$ is considered significant.

Gustilo grade III or IV comminution in 93% of patients. They reported an excellent result of interlocking nailing in their series. In total, 2 delayed unions and 7 malunions were observed in this series. No infection was recorded in any of the patients (10). The infection and nonunion rate was considerably higher in the present series (18% vs. 0% and 26% vs. 3.5%, respectively).

Ogunlusi et al. reported the outcome of gunshot injury

Table 3. The union status in different subgroups of patients with gunshot injury of long-bones

| Variable | Nonunion (n=13) | P value |
|---------------------|-----------------|---------|
| Age | | |
| <20 years | 2 of 7 (28.5) | 0.83 |
| 20-40 years | 8 of 33 (24.2) | |
| >40 years | 3 of 10 (30) | |
| Gender | | |
| Male | 12 of 46 (26.1) | 0.77 |
| Female | 1 of 4 (25) | |
| Smoking | | |
| Yes | 12 of 47 (25.5) | 0.71 |
| No | 1 of 3 (33.3) | |
| Involved bone | | |
| Humerus | 1 of 4 (25) | 0.79 |
| Femur | 9 of 32 (28.1) | |
| Tibia | 3 of 14 (21.4) | |
| Treatment | | |
| Conservative | 0 of 4 (-) | 0.08 |
| Nail | 1 of 10 (10) | |
| Plate | 7 of 18 (38.9) | |
| External fixator | 5 of 18 (27.8) | |
| Gustilo grade | | |
| 3a | 8 of 37 (21.6) | 0.46 |
| 3b | 3 of 8 (37.5) | |
| 3c | 2 of 5 (40) | |
| Vascular injury | | |
| Yes | 4 of 5 (80) | 0.02* |
| No | 9 of 45 (20) | |
| Flap | | |
| Yes | 3 of 12 (25) | 0.44 |
| No | 10 of 38 (26.3) | |
| Masquelet Technique | | |
| Yes | 2 of 7 (28.5) | 0.89 |
| No | 11 of 43 (25.6) | |
| Infection | | |
| Yes | 1 of 9 (11.1) | 0.28 |
| No | 12 of 41 (29.2) | |

Data are presented as nominator of denominator (%).

* $P < 0.05$ is considered significant.

of the diaphyseal femur and tibial fractures grafted with reamed bone marrow and immobilized with an interlocking nail in 36 patients with the mean age of 32.2 ± 12.2 years. The fractures were mainly Gustilo grades I (41.7%) and II (41.7%). Callus formation was observed

in 86.1% of the fractures sites at six weeks, and 5 (13.9%) infection was noted in their patients that were superficial in 4 cases. They attributed their favorable results to the osteogenic and osteoinductive bone marrow (11). All the patients of the present series had Gustilo grade III. The rate of infection and nonunion was higher in this study, which could be attributed to the higher grade of fracture.

Olasinde et al. reported the outcome of gunshot injury of the diaphyseal femur (n=20) and tibia (n=11) that were managed with interlocking nails. The majority of the fractures of this study were Gustilo grades I and II. The union of the fractured bone was achieved in all patients, and infection was the most frequent wound complication (n=5). They concluded that an intramedullary locked nail is an effective method for the treatment of gunshot fractures of the lower extremity (11). Nailing was used for the treatment of 20% of the patient in the present study, and no significant difference was found between the rate of complications and the fixation method.

Hilton et al. aimed to retrospectively review the results of intramedullary nailing for the treatment of 13 patients with gunshot injury of the tibia. The fracture was the Gustilo grade I in six patients, grade II in six patients, and grade IIIa in one patient. The Gustilo grades IIIb and IIIc were excluded from this study because they were not treated by intramedullary nailing. The union of fracture was observed in all patients, and osteomyelitis was recorded in three patients. However, no case of malunion was recorded, and they suggested intramedullary nailing for the treatment of low-grade Gustilo gunshot fractures (12). The rate of postoperative complications was higher in the present series which could be attributed to the higher Gustilo grades.

Thakore et al. assessed the rate of nonunion and infection in open tibia fractures in 486 patients with different Gustilo grades. According to their results, the Gustilo grade was the greatest predictor of nonunion and infection, as Gustilo grade III fracture had much higher rates of infection and nonunion (20.8% and 16.7%) than Gustilo grades I (1.6% and 6.3%) and II (8.4% and 7.4%). In addition, the rate of each complication was different between different subsets of Gustilo grade III. In this respect, the rate of infection was 14% for grade IIIa, 30% for grade IIIb, and 62 % for grade IIIc. The rate of nonunion was 11% for grade IIIa, 26% for grade IIIb, and 25% for grade IIIc (13). The Gustilo grade III fractures were only included in this study. The infection and nonunion rates were 18% and 26%, respectively. The rate of infection was 13.5% in Gustilo grade IIIa, 25% in Gustilo grade IIIb, and 40% in Gustilo grade IIIc in the present series that was smaller than those in a study by Thakore et al. This difference could be attributed to the inclusion of only gunshot injuries in the current study.

According to a study by Gustilo et al., the rate of infection in type III (severe) open fractures ranges between 10% and 50% (14). In the present study, the rate of infection was at the lower extension reported by Gustilo et al. (18%). Therefore, it could be concluded that the rate of infection is lower in gunshot injuries with Gustilo grade III, compared to non-gunshot injuries. This difference could be attributed to the heat generated by the firing of a

bullet that sterilizes the bullet. It could also be attributed to the adequate debridement of the wound and antibiotic prophylaxis in our center. Whatever the reason, the incidence of infection in gunshot injuries with Gustilo grade III should be further investigated in future studies. Brinker et al. reported an increased risk of delayed union and nonunion in tibia fractures with an associated vascular injury (15). The same association was noted in the present study. Therefore, more intensive care might be required to avoid nonunion in these patients (16).

In the present study, skin flap was associated with an increased rate of infection. The same association was reported in a study conducted by Amici et al. (17). Therefore, it is suggested to augment antibiotic prophylaxis in these patients. Earlier studies have revealed an increased rate of infection if soft-tissue coverage is delayed (18, 19). The flap procedure was conducted in this study with no delay. Therefore, the higher rate of infection in patients who had flaps was not the result of the delayed procedure. Instead, it could be attributed to the higher severity and grade of injury in these patients, which required more invasive procedures, leading to a higher risk of infection (20). This study was not without limitations. The main limitation of this study was the small number of patients, particularly in some subsets, such as Gustilo grades IIb and IIc. The small number of patients might have affected the power of statistical analysis as well. Therefore, future large-scale studies are required to confirm the result of this study.

Gunshot injuries of long-bone are associated with a

high incidence of post-treatment infection and nonunion. The rate of infection is higher in patients with a skin flap, and the rate of nonunion is higher in patients who have vascular injuries. Therefore, more intensive care should be taken to avoid these post-treatment complications, particularly in patients with skin flap and vascular injuries.

Compliance with ethical standards: Ethical approval was obtained from the ethics committee of Iran University of Medical Sciences. This study was also in accordance with the Helsinki Declaration and its later amendments and prior entering the study patients gave their informed consent to participate in this study.

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