ORIGINAL ARTICLE

Management of civilian ballistic fractures

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KEYWORDS
Ballistic fracture; Gunshot wound; Civilian; Debridement; Infection

Summary

Introduction: The management of ballistic fractures, which are open fractures, has often been studied in wartime and has benefited from the principles of military surgery with debridement and lavage, and the use of external fixation for bone stabilization.

Hypothesis: In civilian practice, bone stabilization of these fractures is different and is not performed by external fixation.

Patients and methods: Fifteen civilian ballistic fractures, Gustilo II or IIIa, two associated with nerve damage and none with vascular damage, were reviewed. After debridement and lavage, ten internal fixations and five conservative treatments were used.

Results: No superficial or deep surgical site infection was noted. Fourteen of the 15 fractures (93%) healed without reoperation. Eleven of the 15 patients (73%) regained normal function.

Discussion: Ballistic fractures have a bad reputation due to their many complications, including infections. In civilian practice, the use of internal fixation is not responsible for excessive morbidity, provided debridement and lavage are performed. Civilian ballistic fractures, when they are caused by low-velocity firearms, differ from military ballistic fractures. Although the principle of surgical debridement and lavage remains the same, bone stabilization is different and is similar to conventional open fractures.

Level of evidence: Level IV (retrospective study).

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Introduction

Surgeons may encounter gunshot wounds, even outside of military conflicts. In wartime [1,2] and in peacetime [3], gunshot wounds mainly affect the limbs, predominantly the lower limbs.

The lesional spectrum of gunshot wounds of the limbs is wide, ranging from the simple injury to soft tissues to bone injury (ballistic fracture, which is by definition an open fracture), to crushed bone with devascularization of the limb and nerve injury.

These ballistic fractures of the limbs have been mainly studied in armed conflicts in military hospitals. Their management in the civilian setting has long been based on military practices, notably with debridement and lavage, as well as bone stabilization using external fixation.

The objective of this study was to assess the results of surgical management of civilian ballistic fractures that did...
not make use of external fixation. We hypothesize that in civilian settings, the bone stabilization method of these ballistic fractures differs from that used in the military context.

Patients and methods

Between 2008 and 2012, 15 patients (13 males and two females; mean age, 28.5 years, range, 19–55 years), victims of firearm injuries with limb bone involvement (excluding the spine), were surgically managed. All ballistic fractures were caused by 9 mm bullets. In three cases, bone injury was associated with visceral injury, which was always operated first.

Upper limb bone involvement was found in four cases (Fig. 1), and lower limb in 11 cases (Table 1).

Six fractures were comminuted. All fractures were II or IIIa on the Gustilo classification (preoperative confirmation) [4]. Two fractures (13%) were associated with nerve injury (Table 1). In each case, the nerve was continuous on surgical exploration. No fracture was associated with vascular injury.

All the fractures were managed medically in less than 1 h and were operated in the operating room within a mean of 9.7 h after injury (range, 3.5–24 h). Antibiotic therapy was initiated. The choice of antibiotics varied depending on the operators: either amoxicillin + clavulanic acid was administered for at least 48 h or amoxicillin + clavulanic acid + gentamicin for at least 48 h (Table 1).

Surgical technique

Under general anaesthesia, debridement of the entry and exit points as well as lavage of the bullet trajectory in the soft tissue to the bone were performed. Small devascularized fragments were excised; pediculated bone fragments and those with muscle attachment were preserved. A fasciotomy of the muscle compartments was performed systematically. The surgical site was then washed with saline to be sure that no foreign body (notably from clothing) remained in the surgical site.

Depending on the type and stability of the fracture, bone stabilization was or was not provided with internal fixation: in ten cases out of the 15 (67%), internal fixation was used (Table 1) (Figs. 2–4); in five cases (33%), conservative treatment was selected. Primary closing with a drain was carried out.

Figure 1 Entrance (a) and exit point (b), X-rays (c), and 3D CT (d) of a comminute ballistic fracture of the proximal ulna and lateral condyle of the distal humerus.

Figure 2 Internal fixation of the fracture in Fig. 1.
Table 1 Preoperative characteristics.

<table>
<thead>
<tr>
<th>Age(years)</th>
<th>Bone</th>
<th>Nerve lesion</th>
<th>Time to bone surgery(h)</th>
<th>Bone stabilization</th>
<th>Antibiotics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38.3</td>
<td>Femur diaphysis</td>
<td>3</td>
<td>Surgery (plate)</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>19.9</td>
<td>Proximal femur</td>
<td>Sciatic nerve</td>
<td>Surgery (screw-plate)</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>35.8</td>
<td>Proximal femur</td>
<td>11</td>
<td>Surgery (screw-plate)</td>
<td>A</td>
</tr>
<tr>
<td>4</td>
<td>22.9</td>
<td>Femur diaphysis</td>
<td>11</td>
<td>Surgery (plate)</td>
<td>A + G</td>
</tr>
<tr>
<td>5</td>
<td>20.7</td>
<td>Tibia diaphysis</td>
<td>14</td>
<td>Conservative</td>
<td>A + G</td>
</tr>
<tr>
<td>6</td>
<td>28.2</td>
<td>Tarsal bone</td>
<td>5.5</td>
<td>Surgery (screw-plate)</td>
<td>A + G</td>
</tr>
<tr>
<td>7</td>
<td>22.2</td>
<td>Femur diaphysis</td>
<td>4</td>
<td>Surgery (plate)</td>
<td>A + G</td>
</tr>
<tr>
<td>8</td>
<td>27</td>
<td>Distal femur</td>
<td>5.5</td>
<td>Surgery (screw)</td>
<td>A + G</td>
</tr>
<tr>
<td>9</td>
<td>31.2</td>
<td>Ulna diaphysis</td>
<td>24</td>
<td>Surgery (intramedullary wiring)</td>
<td>A + G</td>
</tr>
<tr>
<td>10</td>
<td>23.9</td>
<td>Tibia diaphysis</td>
<td>Deep fibular nerve</td>
<td>Conservative</td>
<td>A</td>
</tr>
<tr>
<td>11</td>
<td>32.6</td>
<td>Proximal ulna + distal humerus</td>
<td>9.5</td>
<td>Surgery (screw + wiring + cerclage)</td>
<td>A</td>
</tr>
<tr>
<td>12</td>
<td>25</td>
<td>Scapula</td>
<td>20.75</td>
<td>Conservative</td>
<td>A</td>
</tr>
<tr>
<td>13</td>
<td>22.9</td>
<td>Iliac wing</td>
<td>7.5</td>
<td>Conservative</td>
<td>A + G</td>
</tr>
<tr>
<td>14</td>
<td>21.4</td>
<td>Finger phalanx</td>
<td>12</td>
<td>Surgery (wiring)</td>
<td>A + G</td>
</tr>
<tr>
<td>15</td>
<td>55.3</td>
<td>Femur diaphysis</td>
<td>5.75</td>
<td>Surgery (plaque)</td>
<td>A + G</td>
</tr>
</tbody>
</table>

A: Augmentin®; G: gentamicin.

Revision

The clinical exam assessed residual postoperative pain (VAS out of 10) and return to work (at the same position or not), a reflection of the functional recuperation of the limb. Bone union was assessed on X-rays. The occurrence of postoperative complications, such as surgical site infection and malunion were recorded.

Statistical analysis was carried out using Statview™ software. We analyzed the following parameters:

- the difference in bone union between surgically stabilized fractures and immobilized fractures using the Fisher exact test;
- the statistical correlation between the time to surgery and bone union, using the Spearman test;
- the difference in postoperative infection between fractures operated before 6 h and those operated after and between the fractures for which only amoxicillin + clavulanic acid was administered and those for which gentamicin was associated, using the Fisher exact test.

Results

Mean follow-up was 24.4 months (range, 6–64 months).

Radiological results

The radiological results are recorded in Table 2: the mean time to bone union of the fractures was 4 months (range, 2–12 months). Fourteen fractures out of the 15 (93%) showed bone union with no reoperation; one required bone grafting at 6 months; union was achieved on the 12th month.
The type of immobilization (internal fixation or conservative treatment), time to surgery (before or after 6 h) did not influence the time to bone union (respectively, \( P = 0.66 \) and \( P = 0.21 \)).

**Complications**

No superficial or deep infection of the surgical site was observed (0/15), no matter what the time to surgery (\( P = 1 \)) or the type of antibiotic therapy (\( P = 1 \)) (Table 2).

**Clinical results**

Mean postoperative residual pain was 1.2/10 (range, 0–7). Eleven patients out of the 15 (73%) recovered normal function of their limb and were able to return to work. For four patients, the insufficient functional result was related to pain (pain \( \geq 3/10 \)) and nerve sequelae (a neurological deficit despite secondary nerve surgery, with total recovery of the other neural deficit) (Table 2).

**Discussion**

**Particular characteristics of the military context**

The differences between the civilian and military environments for the most part concern the challenging conditions of managing the wounded and the type of firearm used.

Military physicians caring for wounded soldiers in war zones face precarious sanitary conditions and limited means of fixation [5]. This is found in the level of wound contamination: the high rate of bacterial contamination in war zones by Clostridium and other bacteria (three to four types on average) was demonstrated as early as World War I. In comparison, open injuries and fractures in the civilian context are often contaminated by one or two types of bacteria (Gram-negative Bacilli and/or Staphylococci) [4], and, after

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Postoperative clinical and radiological results.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone</td>
<td>Time to bone union (months)</td>
</tr>
<tr>
<td>1</td>
<td>Femur diaphysis</td>
</tr>
<tr>
<td>2</td>
<td>Proximal femur</td>
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<tr>
<td>3</td>
<td>Proximal femur</td>
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<td>4</td>
<td>Femur diaphysis</td>
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<td>Tibia diaphysis</td>
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<tr>
<td>11</td>
<td>Proximal ulna + distal humerus</td>
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<tr>
<td>12</td>
<td>Scapula</td>
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<tr>
<td>13</td>
<td>Iliac wing</td>
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<tr>
<td>14</td>
<td>Intermediary phalanx</td>
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<tr>
<td>15</td>
<td>Femur diaphysis</td>
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</table>
surgical debridement, they become sterile, contrary to open injuries and fractures in a military context [6].

Bullets, classified by their speed, are either low-velocity (< 600 m/s) or high-velocity. Low-velocity bullets are classically fired from handguns and high-velocity bullets from long guns, either military or hunting guns. The lesions caused by high-velocity bullets are more serious and extensive: comminution is more severe, the soft tissues more seriously injured, often with torn tissue and more frequent associated vascular and nerve damage [5,7]. The most frequently used firearms by the civilian population are handguns. This was found in the present series, with only six comminute fractures out of 15, the absence of cutaneous tearing, notably in the tibialis segment, and the absence of vascular injury.

These differences are found in the rate of postoperative infection. Historically, infection has been one of the main causes of death in war zones. Recently, this infection rate, both superficial and deep, of the surgical site varies between 30 and 40%, depending on the series [8], which is higher than the infection rate for civilian ballistic fractures [9,10].

This explains the use of external fixators in military ballistic fractures. Initially used systematically and definitively, this external fixation is now integrated into a sequential treatment according to “damage control orthopaedics” (war DCO) and can become temporary with secondary conversion to internal fixation [5].

**Particular features of the civilian context**

Managing bullet wounds and fractures in civilian practice has mostly been evaluated in the United States. The fundamental principle guiding initial surgical management of any gunshot wound, belonging to both the basic principles of military surgery [1,6,11] and civilian surgery, is debridement and lavage.

The term “debridement” designates surgical exposure of the injured area by enlarging the cutaneous wound to provide a complete view of the injured tissues as well as excision of all the necrotizing tissue. Excision of nonviable muscle tissue and bone must only leave bleeding and contractile muscle as well as bone fragments with periosteal or soft tissue attachments. The surgeon’s experience is determinant in recognizing these features.

For us, the quality of the initial debridement and lavage contributes enormously to the absence of both postoperative superficial and bone infection. These results can be found in several series of civilian ballistic fractures [10]. It should be noted that the time to surgery greater than 6 h does not seem to be problematic in terms of infection, which has been noted in recent studies on open fractures [12], nor does immediate skin closing with drainage [13,14]. The use of antibiotics also plays a role in preventing infection, even if Simpson et al. [15] report that they have no influence on low-energy gunshot wounds in civilian practice if surgery has been performed. However, in high-energy gunshot wounds, intravenous antibiotic therapy, generally first-generation cephalosporin for 48 h [15,16], possibly associated with gentamicin if the wound is highly soiled, is necessary.

Bone stabilization in ballistic fractures differs in military and civilian contexts. In the military context, the external fixator is considered to be the choice treatment, whether it is temporary or definitive [5,10]. In civilian practice, bone stabilization of bullet fractures has, however, gone through a number of changes, and differs depending on the bullet velocity.

In the civilian context, low-energy bullet fractures are considered to be Gustilo I or II or even IIIa fractures with moderate lesions to the soft tissues [16,17]. Bone stabilization is based on the fracture’s stability: unstable fractures may require internal surgical stabilization. Low-energy gunshot fractures of the femur were the first to have been studied in civilian practice: in the 1990s in the United States, debridement and traction were performed in the emergency situation and were followed by intramedullary nailing a few days later, with very good results in terms of bone union and infection [18]. Later, other series reported an ever shorter delay before nailing, until immediate nailing was performed, with consistently good results [19]. The same results have been observed with nailing in diaphyseal gunshot fractures of the tibia.

High-energy gunshot fractures, however, are highly comminuted with substantial soft tissue lesions, notably in the leg (Gustilo IIIb or IIIc). Repeated debridement and excisions are often required and the wounds are not immediately closed; external fixation is the treatment of choice in these cases. However, as in the military context, and even more so, definitive external fixation is chosen less and less often, and conversion to internal fixation is increasingly required: this is the “damage control orthopaedics” (DCO) concept in civilian practice [5].

The use of internal fixation in ten of our cases (two-thirds) with no postoperative infectious complications and with a good bone union rate (9/10) shows that internal hardware can be used in handgun ballistic fractures. It should also be noted that the bone union rate of all the fractures of the series is high (14/15, 93%), whereas these fractures are reputed to be difficult to heal. This could be explained by an “osteomuscular decortication by the bullet”: at the time the bullet impacts the bone, the fragment, or these fragments, are not always free or devascularized and can remain pedunculated to muscle attachments. If the surgeon does not excise them, they can behave like “decorticated” osteomuscular fragments.

**Conclusion**

Civilian ballistic fractures, when they are caused by low-velocity firearms, are different from military ballistic fractures. The major difference is the soft tissue involvement, most frequently less substantial. This is the main prognostic factor. Although the surgical principle of debridement and lavage is identical and fundamental, bone stabilization differs. The use of internal fixation in civilian ballistic fractures is not contraindicated, provided that debridement and lavage are done beforehand, because bone union and restoration of function can be obtained, without excess morbidity, notably infectious.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.
References