

# The Use of “Damage Control Orthopedics” Strategy in the Treatment of Severe Gunshot Wounds of the Limbs

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## Abstract

**Objectives:** The objectives of this study were to evaluate the incidence and nature of gunshot wounds of the limbs in the general structure of combat trauma, and study the features of DCO (Damage Control Orthopedics) patient management strategy in the conditions of a regional hospital as a stage of care for this pathology.

**Background:** Limb injuries account for between 52.3% and 60.1% of combat casualties. The problem of surgical management of limb gunshot wounds is of particular relevance at the present stage of active use of firearms. Thus, adequate choice of surgical treatment strategy for limb gunshot wounds is an important condition for preserving life and preventing severe complications in combat casualties.

**Methods:** The study was conducted among 1000 injured from the combat zone during the period from 24.02.22 to 15.04.22. The trauma and orthopedic surgery department of “Dnipropetrovsk Regional Clinical Hospital named after I.I. Mechnikov” mainly performed secondary surgical debridement of wounds, comprehensive surgical and medical prevention of complications in the injured. Injury severity was assessed using the ISS (Injury Severity Score) based on the AIS (Abbreviated Injury Scale), which assesses the severity of injuries to several areas of the body.

**Results:** DCO strategy was used in 287 (55.1%) injured patients in severe and extremely severe condition (16 points or higher on the ISS scale). A total of 602 surgical operations were performed in 287 injured patients. On average, 2.1±0.6 interventions per one injured person were performed. Overall mortality among victims with gunshot wounds of the limbs was 3.6% (19 wounded out of 521). In all cases there were polytrauma (100%), in 4 (21.1%) cases they were through-and-through injuries, in 2 (10.5%) - with the compartment syndrome development.

**Conclusions:** Differentiated DCO strategy in the surgical treatment of the critically and severely injured (16 points and above on the ISS scale) are essential to save the lives of soldiers in the first period of traumatic illness and to prevent complications of the second and third periods of traumatic illness.

**Keywords:** Damage Control Orthopedics, Polytrauma, Gunshot Wounds, Traumatic Amputations, External Fixation Device, Vac-Therapy, Compartment Syndrome

## Background

The problem of surgical management of limb wounds is of particular relevance at the present stage of active use of firearms, which is accompanied by increasing severity, multiplicity and combinations of injuries, complicates their anatomical and functional recovery, results in complications and disablement of the injured [1-3].

According to the 2014-2019 analysis, limb injuries account for between 52.3% and 60.1% of combat casualties. Gunshot fractures of long bones with widespread soft tissue defects and damage of large blood vessels and nerves occurred in 32.5-39.8% of the injured, and as a component of severe polytrauma, gunshot injuries of the extremities were observed in 67.5-74.4% of the injured [4]. Most of the injured had shrapnel injuries of their

limbs (80.4%), of which 70.6% had penetrating, isolated or multiple injuries [5].

Current approaches to the treatment of injured with gunshot wounds of the limbs include early total care (ETC) and multi-stage surgical tactics (damage control orthopedics - DCO) [6,7]. At the same time, ETC is recommended to be used in polytraumatized patients with stable vital functions, while physiologically unstable patients with severe injuries should be treated using stepped therapy such as DCO. It makes it possible to decrease in-hospital mortality in patients with pelvic and long bone fractures, shorter hospital stays and fewer complications [8,9]. On the other hand, Volpin G. et al. there is the concept of safe definitive surgery (SDS), which involves a dynamic synthesis of two treatment strategies - ETC and DCO [10]. The SDS strategy involves selecting a patient management strategy by continuous dynamic assessment of the patient's vital functions and laboratory and instrumental data.

Thus, adequate choice of surgical treatment strategy for limb gunshot wounds is an important condition for preserving life and preventing severe complications in combat casualties.

## Methods

The study was conducted among 1000 injured from the combat zone in the municipal enterprise "Dnipropetrovsk Regional Clinical Hospital named after I.I. Mechnikov" during the period from 24.02.22 to 15.04.22. The hospital corresponds to Level III of medical care and a specialized medical evacuation phase, where the trauma and orthopedic surgery department mainly performs secondary surgical debridement of wounds, comprehensive surgical and medical prevention of complications in the injured [11]. The mean age of the injured was (M±SD) 37.0±6.2 years. The average period from injury to hospitalization was 1.7±0.6 days.

Gunshot injuries of limbs were found in 521 (52.1%) injured, including mine-blast wounds - in 286 (54.9%), shrapnel wounds - in 127 (24.4%), gunshot wounds - in 108 (20.7%). Limb injuries were more frequently found as part of polytrauma (46.8%) and multiple (29.9%) injuries, and isolated wounds occurred in 26.3% of cases. Penetrating wounds were found in 78.3% of cases, through-and-through wounds in 6.7%, and tangential wounds in only 1.5% of cases. Distribution of patients with gunshot wounds to the limbs by type and nature of injury is represented in Table - 1 below.

**Table 1: Distribution of patients with gunshot wounds to the limbs by type and nature of injury**

<i>Characteristics of wounds</i>	<b>Number of the wounded (n=521)</b>	
	<b>Absolute number</b>	<b>%</b>
<i>By the type of wounding projectile:</i>		
- gunshot	108	20.7
- shrapnel	127	24.4
- mine-blast	286	54.9
<i>By the number of damages:</i>		
- isolated	137	26.3
- multiple	140	26.9
- polytrauma	244	46.8
<i>By the nature of the wound:</i>		
- penetrating	408	78.3
- through-and-through	35	6.7
- tangential	8	1.5
- combination of several types of wounds	18	3.5
<i>By type of limb fractures:</i>		
- open	315	60.5
- closed	53	10.2
- upper limb girdle	132	25.4
- lower limb girdle	236	45.3
<i>Traumatic amputations:</i>		
- upper limbs	30	5.8
- lower limbs	40	7.7
<i>By injuries to other structures:</i>		
- soft tissues	344	66.0
- nerves, vessels, tendons	38	7.3

In 70.6% of the total number of limb injuries, there were gunshot fractures of bones, mostly open (60.5%). Fractures of the lower limb girdle bones occurred in 45.3% of the injured, including fractures of the femur in 10.0%, tibia in 19.8%, foot in 6.5%, pelvis and spine in 9.0%. Fractures of the upper limb girdle bones accounted for 25.4%, including fractures of the scapula and clavicle 3.1%, upper arm bone 10.2%, forearm 9.6%, and hand 2.5%.

Traumatic amputations of the upper limbs occurred in 5.8% of the injured and of the lower limbs in 7.7%. Soft tissue wounds were found in 66.0% of cases, and gunshot injuries of nerves and great vessels in 7.3%. Compartment syndrome was found in 3 (0.6%) cases.

Injury severity was assessed using the ISS (Injury Severity Score) based on the AIS (Abbreviated Injury Scale), which assesses the severity of injuries to several areas of the body [12]. The ISS scores range from 1 to 75 and, in contrast to the AIS scale (level 1 to 6), allow assessment of the severity of combined and multiple injuries. Injuries are classified as minor with an ISS score of <9, moderate with an ISS score of 9 to 15, severe with an ISS score of 16 to 25 and extremely severe with an ISS score greater than 25 [13].

### Statistical Analysis

Descriptive statistical analysis was used for creating this research.

### Results

The severity of the gunshot injuries of the limbs on the ISS scale ranged from 2 to 75 points and averaged  $18.2 \pm 12.3$  points. Minor injuries occurred in 106 (20.3%) of the injured, moderate in 128 (24.6%), severe in 162 (31.1%), and extremely severe in 125 (24.0%) of the injured.

DCO strategy was used in 287 (55.1%) injured patients in severe and extremely severe condition (16 points or higher on the ISS scale), because early major orthopedic procedures could cause complications with worsening condition of an unstable polytrauma patient. The basic principles of DCO in such patients are the immediate treatment of life-threatening conditions and primary minimally invasive external fixation of long bone fractures followed by metabolic and respiratory stabilization of patients.

According to DCO strategy, surgical interventions were divided into 2-3 phases. In the first phase, after anti-shock measures and stabilization of hemodynamic indices, the injured patients underwent emergency surgical interventions aimed at stopping internal and external bleeding (thoracotomy, laparotomy, revision of the neurovascular bundle) in the operating room. Later, urgent surgical interventions were performed, which most often included soft tissue surgeries (removal of foreign bodies, primary surgical debridement of wounds) and amputations to identify and eliminate infected and necrotic areas. In the first phase of DCO strategy in severely injured patients there was no full-fledged surgical wound treatment; only interventions to stop external bleeding, washing the wound with antiseptic solutions, local administration of antibiotics and application of aseptic dressing were performed. At the same time, anti-shock therapy was con-

tinued. In the first phase of DCO strategy, the injured nerves were not repaired. At the next stage, after stabilization of the injured (usually on the 2nd or 3rd day), delayed surgical interventions of the second phase of DCO strategy were performed: primary surgical debridement of wounds, external fixation osteosynthesis with external fixation device (EFD), fasciotomy, and Ilizarov external fixation. The wound was then surgically treated again for the next 3-5 days (the wound was opened, revision with removal of necrotic tissues and foreign bodies was performed, the wound cavity was washed and drained). For faster wound debridement and preparing it for closure, 1-2 courses of VAC-therapy were performed. Stabilization of gunshot bone fractures with a frame EFD in 28% of cases was final, in 72% - temporary immobilization until the healing of the gunshot wound. After all vital functions had been stabilized, the next step was elective reconstructive surgery, which included replacing the EFD frame with a plate or intramedullary locking nail, nerve neurolysis, limb amputations and stump formation.

A total of 602 surgical operations were performed in 287 injured patients with severe and extremely severe limb gunshot injuries, on average,  $2.1 \pm 0.6$  interventions per one injured person. Of these, the vast majority were interventions for secondary surgical debridement of wounds (60.6%), fasciotomies (58.9%), osteosynthesis (44.6%).

Overall mortality among victims with gunshot wounds of the limbs was 3.6% (19 wounded out of 521). In all cases there were polytrauma (100%), in 4 (21.1%) cases they were through-and-through injuries, in 2 (10.5%) - with the compartment syndrome development. The average length of treatment for injured patients with gunshot injuries to the limbs was  $7.4 \pm 3.2$  bed-days. To continue treatment in highly specialized medical institutions of the IV level medical evacuation stage, 478 (95.2%) of the injured were sent, 24 (4.8%) - for rehabilitation.

### Discussion

Patients with polytrauma always have significant disturbances in the homeostasis [14]. There are still discussions about the choice of strategy for managing a patient with polytrauma - DCO, ETC or the recently developed concept of SDS [10]. But there is another group of patients with even more difficult strategy making decision. These are patients with gunshot wounds to the extremities.

For traumatized patients, the indications for the use of one or another strategy can vary and be taken individually in each case. Nevertheless, patients with gunshot wounds and especially patients with polytrauma received during a wartime, must be managed with DCO strategy. There are a number of reasons for this.

First of all, the so-called molecular concussion zone is observed in all patients with gunshot wounds. In this zone changes occur at the molecular level, but necrotic changes have not developed yet. The chosen strategy of patient management will influence the degree of necrosis appearing and the rate of its spreading. That is why we recommend to use the DCO strategy.

According to this strategy, we performed exclusively staged surgical interventions and debridement of gunshot wounds. De-

bridement consisted in removal of non-viable tissues until the appearing of blood dew.

Using this strategy, it was possible to reduce the amount of necrobiotic changes in the molecular concussion zone and stop its spreading. Otherwise, managing the patients with the ETC strategy would lead to the necrotic area spreading and would increase the number of infectious complications [10].

Secondly, gunshot wounds often lead to damage of the neurovascular bundle (7.3% out of 521 injured), which is followed by loss of circulating blood volume, decompensation of organs and systems, worsening of the patient's general condition and the development of shock [15]. With such a pronounced decompensation of organs and systems, it is not recommended to manage patients with ETC strategy. In this case ETC will act as a second hit, which will deteriorate already decompensated patient's condition [16].

With DCO strategy we performed all surgical interventions only after stabilization of the patients' general condition.

Thirdly, gunshot wounds could lead to the damage of a large amount of tissues, for example skin, fascia, muscles, tendons, bones, ligaments, nerves, blood vessels. Such massive injuries put into question the viability and functionality of the injured limb and make it impossible to manage the patient with ETC strategy. For example, if a patient has a gunshot fracture of a limb with a large skin defect, we cannot perform ORIF until the skin defect is closed. Instead, we have to perform temporary fixation of the fracture with an EFD, followed by the closure of the skin defect. Only after these steps we can perform ORIF in the future.

We observed a huge number of patients with gunshot fractures and soft tissue defects, and only applying DCO strategy allowed us to both close the soft tissue defect and fix open fractures. Therefore, only DCO strategy will be able to provide a staged restoration of damaged structures with the subsequent performance of reconstructive and restorative surgeries.

We believe that all these reasons confirm the necessity of applying the DCO strategy in the management of gunshot wounds of the limbs.

## Conclusions

Differentiated DCO strategy in the surgical treatment of the critically and severely injured (16 points and above on the ISS scale) are essential to save the life of soldiers in the first period of traumatic illness and to prevent complications of the second and third periods.

In the first phase of DCO strategy, anti-shock measures are taken to stop bleeding, provide pain relief, apply an aseptic dressing and immobilize the limb. The application of an EFD is possible only after the patient is stabilized.

In the second phase of DCO strategy, repeated and secondary surgical treatment of wounds with fasciotomies, use of vacuum therapy are performed.

In the third phase of DCO strategy, reconstructive surgical interventions are used, in case of gunshot fractures of long bones - replacement of the EFD with a plate or intramedullary locked nail.

## Declarations

### Ethical Approval

The study was approved by the ethics committee of the Regional Clinical Hospital named after II Mechnikov (IRB number: №2-8/23). All methods have been performed in accordance with the Declaration of Helsinki and written informed consent was obtained from all participants. All methods were carried out in accordance with relevant guidelines and regulations.

### Consent for Publication

The consent for publication is not applicable for this study.

### Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

### Competing Interests

The authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

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### Authors' Contributions

Domanskiy A.M. wrote the main manuscript text, Tomilin V.M. collected the data and edited the text, Tomilin M.V. processed statistical data and wrote the text. All authors reviewed the manuscript.

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### Abbreviations

DCO – damage control orthopedic  
ETC – early total care  
SDS – safe definitely surgery  
ISS – Injury Severity Score  
AIS – Abbreviated Injury Scale  
EVD – external fixation device  
VAC – vacuum assisted closure

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