

The Analysis of Limb Amputations Among the Victims of War in the East of Ukraine

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Abstract: *Aim: to study the main reasons that led to the execution of amputation during the combat conflict in the East of Ukraine.*

Materials and methods. The causes of limb amputation are analyzed among 159 victims of the combat conflict in Eastern Ukraine. The average age of the wounded at the time of getting injured made up 33,04±1,15 years (from 18,9 to 60,3 years old); 158 (99,4%) of the wounded were male, 1 (0,6%) - female.

Results: 130 (81,8%) injured lost one limb segment, 29 (18,2%) wounded had multiple limb amputations. In total, 191 operations on limb segment amputation were performed for 159 patients (1,2 amputations per 1 wounded). The causes for the amputation were: 99 (51,8%) amputations were performed because of the traumatic avulsion of limb; 36 (18,8%) – caused by the irreversible limb ischemia as a result of the great vessel injury; 28 (14,7%) – caused by the massive areas of limb primary necrosis caused by mine-blast injuries; 13 (6,8%) – caused by the freezing injury; 5 (2,6%) – caused by the traumatic crush of the limb because of the explosive injury; 3 (1,6%) – caused by the massive areas of limb secondary necrosis; 2 (1,0%) – caused by the crush-syndrome, 1 (0,5%) – caused by the limb putrefactive phlegmon. In 4 (2,1%) cases the cause of the limb amputation was not reliably identified with the lack of proper medical documentation. In 70,6% of the cases the causes of limb amputation were related to the simultaneous occurrence of irreversible changes in the limb resulted from the action of high-energy factors (a powerful blast wave, debris with large kinetic energy, gas-flame mixture, hitting by train). Instead, in 29,4% of cases limb amputation was performed as a result of the gradual formation of irreversible changes in the limb. In part of these cases the limb amputation could have been prevented (or its level could have been reduced) by optimizing organizational-tactical and medical-evacuation measures.

Conclusion: The reasons of limb amputation in most cases are bound to single-step emergence of irreversible changes in a limb which are caused by action of high-energy factors: a potent blast wave, fragments with big kinetic energy, mixture of gas and flame, train run over. But about quarter of limb amputation caused by gradual formation of irreversible changes in a limb (irreversible ischemia of a limb; limb freezing injuries; secondary necrosis; crush syndrome and putrefactive phlegmon). In these cases it was possible to prevent limb amputation (or to reduce its level) by optimization of organizational, tactical, medical and evacuation actions.

Keywords: combat injury; East of Ukraine; limb amputation; modern war.

1. Introduction

In past several years the problem of treatment for patients with the gunshot wounds from the mortar attacks and reactive artillery shelling during the ongoing combat conflict in the East of Ukraine becomes more important and actual. A significant part of patients with gunshot wounds have upper and lower limbs injuries, that lead to the limb segment loss either directly (injury of major vessels, mine-blast avulsion, crushing explosive) or through its complications [2, 3, 6, 11, 12].

During the combat conflict in the East of Ukraine a multilevel medical care is provided to the seriously injured wounded, which includes pre-hospital and hospital stage of treatment. First medical care and predoctor care (baseline) and first medical aid (I level) are given to the wounded on the prehospital stage of treatment. First aid is provided at the wound place in order of the self-aid and mutual aid, then the wounded is evacuated to the nearest place of qualified medical care by sanitary transport. If evacuation to the place of qualified medical care is impossible during 1 hour (the principle of the "golden hour"), in this case the first medical aid is provided at the deployed stabilization points where there are specialists doctors in urgent conditions. First aid is provided by nurses during the evacuation measures [1, 5, 8, 9, 11].

Hospital stage of treatment in the ATO area includes II, III,

IV and V levels of medical care. Qualified surgical treatment (second level) is provided in city and district hospitals, which includes enhancement groups of military doctors, as well as deployed military mobile hospitals. Mentioned medical facilities are installed at the minimum allowable proximity to the contact line, contributing to the 80% of the wounded the implementation of the principle of the "golden hour". On the qualified medical aid stage the wounded gets usually within 60 minutes after the injury.

Specialized surgical care (III level) is provided in one of the three frontline multi hospitals: Military Medical Clinical Center of the North Region (Kharkov), Dnipropetrovsk military hospital (Dnipro) and I.I. Mechnikov Regional Clinical Hospital (Dnipro). Evacuation terms at the third level of treatment is determined by the time needed for the stabilization of hemodynamic victim. The evacuation of this level is executed by motor vehicles (resuscitation car), rail (trains "InterCity") and air transport (helicopters).

IV level of medical care provides an exhaustive list of specialized care using high-tech equipment. This level of care is provided by the National (Kyiv) or regional military medical clinic centers (Vinnytsya, Odessa, Lviv) where victims are evacuated by air.

V level of care includes providing the rehabilitation

measures (containing prosthetic limbs lost segment) in the respective military and civil medical facilities.

Availability and accessibility of modern high-tech equipment, arthroscopy system to VAC therapy, modern prosthetic - orthopedic provision during specialized surgical aid plays an important role in safekeeping of the injured limb segment [4, 10, 11].

The *aim* of our research is to study the main reasons that led to the execution of amputation during the combat conflict in the East of Ukraine.

2. Materials and methods

The results of treatment after amputations among 159 casualties were analyzed. All wounds were received in the combat zone of conflict in Donetsk and Lugansk regions of Ukraine from 06.01.14 to 06.30.16.

All casualties belonged to the military forces and participated directly in military clashes and had the status of combatants. The wounded and the casualties who had no status of combatants (civilians, journalists, employees of military utilities and civil administrations, government emergency service rescuers) but injuries in the area of clashes that led to the amputation of limbs - are excluded from the present research because they were treated primarily in medical facilities of the Ukraine's healthcare system and the systematic data on the results of such is missing.

Due to the fact that each security agency of Ukraine has a system of department medical institutions, the vast majority of injured (154 or 96.9%) served with the Armed Forces of Ukraine. Whereas 4 (2.5%) of casualties served with the Ministry of Internal Affairs of Ukraine, and 1 (0.6%) - with the volunteer battalion.

The average age of studied patients at the time of getting injured was $33,04 \pm 1,15$ years, the youngest was 18,9 years old, the oldest - 60.3 years. In fact, within the combat zone, the troops mostly consist of men (excluding medical workers and journalists), that is why almost all amputations were performed on men (158 or 99.4%) and only one case - on a woman (0.6%). The average term of military service at the time of receiving injury was $1,97 \pm 0,41$ years (from 11 days to 25.2 years). This statement is connected to the fact that most of soldiers represented the mobilized reservists or voluntarily signed a contract for military service after the beginning of combat conflict in the East of Ukraine in 2014.

The main type of damage that led to the loss of a limb segment were mine-blast injuries (119 victims, 74.8%), fragment wounds (15, 9.4%) and bullet gunshot wounds (11, 6.9%), cold traumas (7, 4.4%). 3 (1.9%) suffered injuries were occurred by armor effect (blast injury, while in armored vehicles), 2 (1.3%) - train collision and 2 (1.3%) - concrete structures collapse as a result of the explosion at the Donetsk airport, leading to the prolonged compression syndrome limbs. Among the 119 injured from mine-explosive injuries in 69 (58.0%) injured circumstances were shelling from mortars or rocket launchers, 18 (15.1%) - explosion on mine stretch, 14 (11.8%) - uncontrolled detonation of the EOD, 4 (3.4%) - blast primer grenades in hand and 1 (0.8%) affected - tank firing. 13 (10.9%) of the casualties, a number of reasons (provided medical care in captivity, complex combat environment, the wounded man found unconscious after a certain time after the injury) could not exactly determine the cause of mine-blast injuries in lack of medical documentation or its improper usage.

The following *criteria for including* the patients into the research were taken in consideration for the real-time realization of the research aim:

1. Place of received damage: combat zone of the conflict in districts of Donetsk and Lugansk regions of Ukraine.
2. Time of received injures: from 01.06.14 to 30.06.16.
3. The status of the wounded in the combat confrontation: the injured at the time of injuring had a combatant status.
4. The nature of the wounded: any injure what led to the loss of limb segment.
5. The nature of surgery: patients who performed disarticulation amputation or disarticulation of the limb segment, including surgeries in the volume of primary surgical treatment of wounded limbs regarding its traumatic separation.
6. Place of medical care at the hospital stage: departmental medical facilities of the Ministry of Defense of Ukraine (mandatory); civilian medical facilities (optional - some stages in some patients).
7. The casualty's observation period: the period of injury and patient identification (liberation from captivity after the injury) before rehabilitation or casualty death.

Criteria for exclusion from the research:

1. Place of received damage: outside of the combat conflict in districts of Donetsk and Lugansk regions of Ukraine.
2. Time of received injures: before 06/01/14 or after 30/06/16.
3. The status of the wounded in the combat confrontation: civilians, volunteers, journalists, public utilities military and civil administration, civil service emergency rescues.
4. The nature of the wounded: any injure what did not lead to the loss of limbs segment.
5. Place of medical care at the hospital stage: departmental medical facilities of the Ministry of Internal Affairs of Ukraine, Security Service of Ukraine, State Border Service of Ukraine.
6. The casualty's observation period: the lack of reliable documentary about the nature of medical care at any level of hospital stage before rehabilitation or patient death.

3. Results

Most affected casualties during combat conflict in the East of Ukraine lost only one limb segment (130 or 81.8%), whereas patients with limb amputation of several segments were significantly less (29, 18,2%; $p < 0,001$). Respectively, only 2 (1.3%) patients were involved in simultaneously limbs amputation of three and four segments. The main reason caused amputation of these patients was freezing extremities of IV degree. There weren't casualties affected by mine-explosive wounds among patients who underwent amputation of more than one limb segment because casualties with such multiple wounds died before admission to the hospital phase of medical care. In total 191 surgeries of amputation limb segment (average 1.2 amputation per 1 wounded) executed for 159 patients.

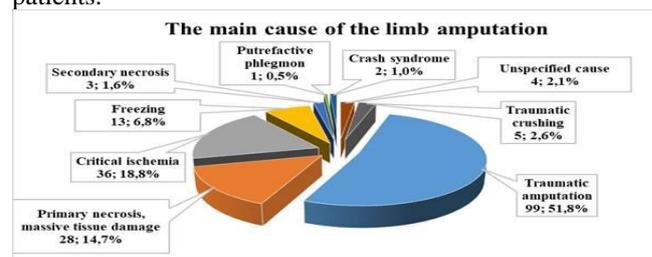


Figure 1. The structure of the main causes that led to the limb amputation

4. Results

Fig. 1 systematized the main reasons that led to the amputation limb segment of the casualties. Most often surgery type of amputation limb segment was executed due to its **traumatic separation** (99, 51.8%). The vast majority of traumatic limb segment separation was associated with the effect of factors affection of mine-explosive wounds - 93 (93.9%). 3 (3.0%) cases of traumatic limb segment separation were the result of a train collision, 2 (2.0%) cases of traumatic amputation occurred by armor effect (blast injury, while in armored personnel carrier), 1 (1, 0%) casualty had foot traumatic amputation as a result of shrapnel wound.

The second the most frequent cause of amputation limb segment was the irreversible **extremity limb ischemia** which arose as a result of wound to major vessels - 36 (18.8%). 16 (44.4%) cases of critical limb segment ischemia developed as a result of mine-explosive wounds of limb segment. 10 (27.8%) cases of damage artery trunk were caused by shrapnel wounds. 9 (25.0%) cases, amputation of limbs segment had the connection with a bullet gunshot wound to the trunk of the vessel. 1 (2.8%) amputation reason was the collapse of the walls during the shelling that caused lots of fracture of the left leg with damage to the neurovascular bundle (since the wound occurred during the defense Donetsk airport terminal, which was surrounded - qualified surgical medical care was postponed, after the development of irreversible ischemic limbs).

It is always considered the possibility of a temporary bypass allovenous or autovenous shunting of ischemic limb areas in case of great vessels wound. However, taken in consideration the massive tissue damage when exposed limbs explosive munitions actions severe condition of the wound, organizational tactical circumstances - shunt operations were not performed for most of researched patients. It is well known that only 3 (8.3%) patients with wounds of the main neurovascular bundle had the shunt surgery at the III level of medical care. In all mentioned causes, there was a shunt thrombosis with the development of irreversible ischemic limb segment. Cases of successful shunting of the vessels in our research were not included because such patients did not have the amputation (criteria for inclusion to the research was the amputation of a limb segment).

28 (14.7%) cases leading to the amputation of limb segment were lots of opened gunshot fragments with **massive primary necrotic areas** of soft tissues at the place of wound. In such cases, amputated limb segment was identified as a non-pillar or non-functional, even with a favorable course of wound process. The most common cause of severe lesions were mine-explosive wounds (20, 71.4%) and multiple shards wounds (5, 17.9%). 2 (7.1%) cases of massive damage of limbs caused by armor wounds (blast trauma) and 1 (3.6%) - with bullet gunshot wound limb (sniper firing).

3 (1.6%) cases, caused limb amputation segment, had the **secondary necrosis of soft tissues of the limb** during the long period after the injury. Thus, in 2 cases, amputation was performed at the level of the middle third of the tibia in the emergence of irreversible changes in the soft tissues on the 26th day after patient got the cold trauma with atherosclerosis of the arteries of the lower extremities on the background of the ineffectiveness of conservative therapy. Additionally, 1 casualty had the lower limb amputation at the level of the middle third of the thigh because of the advent of massive areas

of tissue secondary necrosis limbs on the 9th day after the mine-explosive wound.

13 (6.8%) cases of amputation triggered by cold extremity trauma that caused the 4th degree limb segment **frostbite**.

5 (2.6%) amputations were performed because of the **crushing** of the traumatic limb segment. In all cases, the cause of crushing traumatic limb segment was the mine-explosive wound.

Unspecified cause of limb amputation. 4 (2.1%) cases failed to identify the authentic cause of executed amputation because the qualified surgical medical care was provided to them in captivity and after an exchange of military prisoners' medical records of the nature of wound were not provided by enemy side. Within found out of data history it was identified that 3 cases likely caused the amputation limb segment was mine-explosive wound, and in 1 case performed amputation of the lower extremity at the level of the middle third of the thigh due to bullet gunshot or shrapnel thigh wound likely to damage neurovascular pinch.

2 (1.0%) cases, amputation of the limb segment made because of the development of **crush syndrome**. 1 patient had the crush syndrome arose because of the prolonged limb compression as a result of the collapse concrete slabs under the explosion, he stayed under the rubble about 2 hours. Evacuation and skilled surgical care were postponed (one day after the injury) because the casualty was blocked on the territory of Donetsk airport. The wounded limb was amputated at the lower level of the middle third of the right thigh. 1 wounded crush syndrome resulting from mine and explosive wound that caused lots of fractured right femur and tibia bones of the upper third of the right peroneal nerve damage and blockage pillars of dugout. Amputation of right lower extremity at the level of the middle third of the thigh was executed for the patient.

1 (0.5%) patient cause loss of limbs became **putrefactive phlegmon** of the left lower limb, which at the 3rd day wound complicated course of disease of the patient with mine-explosive wound (open antipersonnel lots fracture of the upper third of the left femur, fracture open firearm left foot with a defect destruction of soft and bone tissues, a common wound of soft tissue defects in the area of the left buttock and left thigh). Due to the ineffectiveness of the other medical measures to prevent the spread of abscess inflammation within the injured body carried out disarticulation of the left lower limb in the joint hip.

5. Discussion

In today's combat conflict among the 191 documented cases of limb segment amputations, in 187 (97.9%) cases the causes of amputation were reliably verified. 169 (88.5%) cases of limb loss were associated with the direct impact of weapons (combat injury). While in 8 (9.4%) cases there was a non-combat injury (frostbite, hitting train). Analyzing the causes of limb amputations during combat conflict in the East of Ukraine consider it appropriate to divide them into two principal groups. The first group - a reasons that instantly cause irreversible changes of limbs and that cannot be corrected by medical methods: blast, fragments with great kinetic energy, gas and fiery mix, hitting train. Second group - reasons for the gradual development of irreversible changes of limbs and can be corrected by medical methods.

Causes of the first group promote pathomorphological changes, which lead to amputation of the limb segment (132, 69.1% observations):

- traumatic avulsion of limb segment as a result of factors lesions mine-explosive injury: mine- explosive wounds, fragments with great kinetic energy - 96 (50.3%) cases;

- massive zone of primary tissue necrosis that caused the action shock-flame and gas and fiery mix at the mine-explosive wounds injuries (22, or 11.5%) and massive fragmentation wounds (5 or 2.6%); in one case (0.5%) gunshot wound resulted in massive areas of primary extremity tissue necrosis, which led to its amputation;

- traumatic crushing limb tissue caused by the action of shock blast, which spread over the course of the main neurovascular bundle and led to considerable mechanical destruction of soft Limb tissues that do not give hope for her recovery supporting / functionally ability in the future - 5 (2.6%) accidents;

- traumatic amputation of limbs as a result of train collision - 3 (1.6%) cases;

The reasons of the second group causing these pathomorphologic changes of limb tissues that were showing her amputation (55, 28.8% of cases):

- injury major vessel to the development of irreversible ischemic limbs segment; these injuries are caused debris with huge kinetic energy (insufficient limb segment separation) and missile wound - 35 (18.3%) observations;

- irreversible limb ischemia caused by damage major vessel of bone fragments in the collapse of concrete structures - 1 (0.5%) case;

- freezing segment limbs in winter time - 13 (6.8%) observations;

- massive necrosis secondary zone with ineffective conservative treatment of cold injuries of extremities - 2 (1.0%) surveillance;

- a massive area of secondary necrosis resulting from mine-blast injury – 1 (0.5%) case;

- crush syndrome - 2 (1.0%) surveillance;

- putrefactive limbs cellulitis - 1 (0.5%) case.

Overall amputations conditioned by reasons of the first group of 132 (69.1%) cases, the second group - in 55 (28.8%) observations. In 4 (2.1%) cases - amputation exact cause could not be determined.

Amputation caused by reasons of the first group is inevitable, as high-caused factors: strong blast, broken shell with high kinetic energy, mechanical limbs amputation at running train. In such cases actually performed not actually amputation of limbs (as herself amputation occurred even during injury - traumatic separation) and primary debridement of wounds on the type of amputation. In other cases, energy blast, debris, gas flame or a mixture of balls was not enough to separation traumatic limb, but they cause severe morphological segment extremity fracture (traumatic crush injury, massive primary areas of necrosis), which makes its further operation impossible even with timely provision of comprehensive specialized care. In this situation perform amputation is independent of time and volume of care.

Reasons for amputation of the second group in nature may be disgusting. Thus, freezing limbs can be avoided by improving conditions of personnel stay at the forefront in winter time. In the rubble of the affected concrete structures important to free him from the rubble (preventing crush-syndrome) and provide adequate transport immobilization of

bone fragments (prevention damage to major vessels) with timely evacuation to hospital stage health care.

Among the causes of limb amputations second group should stay on the amputation caused injury and major vessels their subsequent irreversible ischemia (18.3% of cases).

Separately, among causes of the second group limb amputations, it is necessary to dwell on amputations caused by the injury of great vessels and their subsequent irreversible ischemia (18.3% of observations). It is due to this category of injuries it is possible to significantly reduce the percentage of casualties of limbs loss. The main causes of irreversible ischemia of these patients were the violation of rules of imposing hemostatic tourniquet, belated delivery of the specialized angiosurgical care, inadequate provision of military doctors with vascular allo-prostheses and the lack of skills of general military surgeons in the vessel suture formation. The following directions concerning the reduction of frequency of limb amputations caused by irreversible ischemia are seen – practical training among the military personnel on the rules of hemostatic tourniquet application, maximal approximation of specialized angiosurgical care to the contact line (the "golden hour" concept), reducing the time of casualties evacuation by a wider introduction of airmobile evacuation, material provision improvement and practical trainings with general military surgeons on vessel suturing at the stage of qualified surgery.

6. Conclusions

In the conditions of the modern military conflict limb amputation can be caused by both a combat (88,5%), and a non-combat trauma (9,4%). The reasons of limb amputation in most cases (69,1%) are bound to single-step emergence of irreversible changes in a limb which are caused by action of high-energy factors: a potent blast wave, fragments with big kinetic energy, mixture of gas and flame, train run over. In such cases limb amputation doesn't depend on time and the volume of health care provision. But limb amputation was carried out to 28,8% of cases as a result of the gradual formation of irreversible changes in a limb: wounds of the main vessel that led to an irreversible ischemia of a limb; limb freezing injuries; massive zones of a secondary necrosis as a result of mine-blast or cold trauma; crush syndrome and putrefactive phlegmon of a limb. Regarding such cases, it was possible to prevent limb amputation (or to reduce its level) by optimization of organizational, tactical, medical and evacuation actions.

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Conflict of interest statement

The authors declare no conflict of interest.

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