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Application of surgical technologies for the treatment of victims with long bone defects due to modern combat trauma

S. Guryev [1], S. Hariyan [2], V. Kushnir [1], O. Tsybulsky [2]

[1] SI «Ukrainian Scientific and Practical Center for Emergency Care and Disaster Medicine of the Ministry of Health of Ukraine», Kyiv
[2] MI «Ternopil Regional Clinical Hospital». Ukraine

Modern combat operations cause severe injuries to humans due to the impact of new, more intense means of destruction. Objective. To determine the general structure of the application of medical technologies for the surgical treatment of victims with defects of long bones due to modern combat trauma. Materials and methods. The study is of a cohort nature, conducted in accordance with the requirements and criteria of evidence-based medicine with the level of evidence II b Oxford. The study array consisted of 115 cases of long bone defects in victims with combat trauma. This study was conducted in compliance with the requirements of the Declaration of Helsinki, approved by the Bioethics Commission of the State Research Institute «Ukrainian Scientific and Practical Center of Emergency Medical Care and Disaster Medicine of the Ministry of Health of Ukraine». Results. The study found that in the general population of victims with long bone defects due to combat trauma, the following technologies were most often used: retrograde bone transport 29.35 %, Masquelet technology 27.17 %, antegrade bone transport 21.74 %. It was also found that only Masquelet technology is used in the surgical treatment of long bone defects of all limb segments. The choice of technology for the treatment of long bone defects probably depends on the limb segment. All of the listed technologies were used on the distal segment of the lower limb, but to varying degrees. Conclusions. In the treatment of long bone defects due to modern combat trauma, technologies are diverse, including both the latest and classic approaches. Masquelet technology is the method of choice for surgical treatment of victims of modern combat trauma with bone defects of the long bones of the upper limb and the proximal segment of the lower limb. Antegrade transport technology is the method of choice for the distal segment of the lower limb. The use of a specific technology for surgical treatment of bone defects due to modern combat trauma evidently depends on the characteristics of the affected segment. Further careful research is needed to reliably explain this fact.

Особливістю сучасних бойових дій є застосування новітніх інтенсивніших засобів ураження і, як наслідок — тяжкіші ушкодження людини. Мета. Визначити загальну структуру застосування медичних технологій хірургічного лікування постраждалих із дефектами довгих кісток унаслідок бойової травми. Методи. Робота має когортний характер, проведена відповідно до вимог і критеріїв доказової медицини зі забезпеченням рівня доказовості IIb Oxford. Масив дослідження склав 115 випадків дефектів довгих кісток у постраждалих із бойовою травмою. Результати. Виявлено, що в пацієнтів із дефектами довгих кісток унаслідок бойової травми в загальному масиві найчастіше застосовувались такі технології: антеградний кістковий транспорт — 29,35 %, Masquelet — 27,17 %, ретроградний кістковий транспорт — 21,74 %. Доведено, що лише технологія Masquelet застосовується для хірургічного лікування дефектів довгих кісток усіх сегментів кінцівок. Вибір методики лікування таких дефектів вірогідно залежить від сегмента кінцівок. На дистальному сегменті нижньої кінцівки застосовувалися в різній мірі всі перелічені способи. Висновки. Існують різноманітні методики лікування дефектів довгих кісток унаслідок сучасної бойової травми — як новітні, так і класичні. Технологія Masquelet є методом вибору хірургічного втручання постраждалих унаслідок сучасної бойової травми з дефектами довгих кісток верхньої кінцівки та проксимального сегмента нижньої кінцівки. Спосіб антеградного транспорту використовується в разі ураження дистального сегмента нижньої кінцівки. Застосування конкретної методики оперативного втручання в разі кісткових дефектів здебільшого залежить від зони ураження. Для достовірного пояснення цього факту потрібні подальші ретельні дослідження. Ключові слова. Довгі кістки, дефекти, розміри, хірургічне лікування, технології.

Keywords. Long bones, defects, sizes, surgical treatment, technologies

Introduction

The ongoing modern combat operations on Ukrainian territory result in severe injuries to individuals due to the impact of newer, more intensive means of destruction. Today, the analysis of these injuries shows that 50–65 % of them affect the extremities [1, 2], often accompanied by significant damage to both bones and soft tissues. This leads to an increased risk of defects in long bones, both primary and secondary in nature [3, 4].

Unfortunately, the effectiveness of treatment for patients with long bone defects caused by combat injuries in Ukraine, as in the rest of the world, cannot be considered satisfactory due to the absence of a unified system for surgical treatment methods. The variety of defect characteristics and their extent demands a certain level of standardization in the use of these treatment methods. To develop such a system, it is critically important to study and analyze the surgical intervention techniques applied to patients with long bone defects [5-8].

All of the above emphasizes the necessity, relevance, and nature of this study. This publication is the first report of our observations and focuses solely on the general characteristics of surgical technologies used to treat patients with long bone defects resulting from combat trauma.

Objective: to determine the overall structure of the application of medical surgical technologies in the treatment of patients with long bone defects resulting from combat trauma.

Materials and Methods

This study is of a cohort nature, conducted according to the requirements and criteria of evidence-based medicine with a level of evidence IIb, as per Oxford classification. It includes 115 cases of long bone defects in patients with combat trauma, selected through irreversible randomization from a total pool of 5,000 cases.

We performed an analysis of the medical records of the patients with respect to the use of surgical treatment methods for bone defects. Under these conditions, evaluating the correctness and appropriateness of a particular method was deemed adequate by default.

Upon primary examination of the actual data, we found that the following surgical treatment technologies were applied: Masquelet technique, antegrade bone transport, retrograde bone transport, "antegrade + retrograde bone transport", bifocal limb lengthening, trifocal limb lengthening, bone plastic surgery, length correction, and acute shortening.

A parametric (rank) and non-parametric (polychoric) analysis of the study material was conducted using elements of fractal analysis. Data processing was performed using computer technologies.

The study was carried out in accordance with the requirements and criteria of evidence-based medicine, adhering to the principles of the Helsinki Declaration and the laws of Ukraine, approved by the Bioethics Commission of the State Enterprise "Ukrainian Scientific-Practical Center for Emergency Medical Care and Disaster Medicine of the Ministry of Health of Ukraine", protocol No. 4 dated 12.11.2025. All patients provided informed consent.

Results

The aim of our study implied a general analysis of the application of surgical treatment technologies for large bone defects in the total sample (Table 1).

It was found that, among patients with long bone defects, anterograde bone transport was the most commonly used technique (29.35 %), ranking first, followed by Masquelet in second place (27.17 %), and retrograde bone transport in third (21.74 %). The smallest proportion (the last, seventh rank) was occupied by bifocal lengthening and acute shortening, both at 1.09 %. The ratio of the maximum to minimum values is 26.93, indicating high dissipation of the distribution and indirectly pointing to the reliability of these results.

For a more detailed study of the issue of the use of surgical intervention technologies, the sample of patients with long bone defects was divided into groups by the location of the injured area of the limbs and treatment methods (Table 2).

Data analysis, presented in Table 2, showed the following: first, there is no overlap in the ranking positions of surgical treatment technologies across the anatomical segments of the limbs; second, for defects of the proximal limb segments, Masquelet is used most often. It is applied twice as often on the proximal part of the upper limb as it is on the lower limb.

In the distal parts of the limb segments, there is a significant difference between the upper and lower limbs. In the first case (forearm), Masquelet was used, and in volumes similar to those in the proximal limb part. Bone plastic surgery was also applied in cases of defects in the proximal part of the upper limb.

During the surgical treatment of bone defects in the distal part of the upper limb, in addition to Masquelet, technologies such as anterograde bone transport and length correction were used (both 14.29 %).

Table 1

Analysis of the application of various surgical approaches for treating long bone defects

Technology	Percentage (%)	Rank
Masquelet	27.17	2
Anterograde bone transport	29.35	1
Retrograde bone transport	21.74	3
Anterograde + retrograde bone transport	3.26	6
Bifocal limb lengthening	1.09	8
Trifocal limb lengthening	2.17	7
Bone grafting	4.35	5
Length correction	9.78	4
Acute shortening	1.09	8

Table 2

Study of the cohort of patients in groups based on injury segment and intervention

Technology	Shoulder	Rank	Forearm	Rank	Hip	Rank	Tibia	Rank	Total
	percentage (%)		percentage (%)		percentage (%)		percentage (%)		percentage (%)
Masquelet	80.00	1	71.42	1	38.89	1	14.52	3	27.17
Anterograde bone transport	0	3	14.29	2	16.67	3	37.09	1	29.35
Retrograde bone transport	0	3	0	3	27.77	2	25.80	2	21.74
Anterograde + retrograde bone transport	0	3	0	3	0	4	4.84	5	3.26
Bifocal limb lengthening	0	3	0	3	0	4	1.61	7	1.09
Trifocal limb lengthening	0	3	0	3	0	4	3.22	6	2.17
Bone grafting	20.00	2	0	3	0	4	3.22	6	4.35
Length correction	0	3	14.29	2	16.67	3	8.06	4	9.78
Acute shortening	0	3	0	3	0	4	1.61	7	1.09

When treating bone defects in the proximal segment of the lower limb, two key observations stand out: Masquelet is used half as often, and there is a wider range of other techniques employed, including retrograde and anterograde bone transport, as well as length correction.

For defects in the distal part of the lower limb, bone transport is predominantly used (anterograde — 37.09 % and retrograde — 25.80 %). Masquelet was used much less, in only 14.52 % of cases, and length correction in 8.06 %. Other methods used included bifocal and trifocal limb lengthening, and, interestingly, acute shortening of the limb.

In summary, it can be noted that during the surgical treatment of bone defects in both the upper and lower limbs, technologies were applied to varying extents.

To further examine the frequency of use of different surgical treatment technologies in patients with long bone defects, we divided the patients into groups based on the injured segment of the limb (Table 3).

It was found that only Masquelet was used during surgeries for long bone defects in all segments of the limbs. This method is most frequently used for defects in the distal part of the lower limb (36.00 %), and least frequently on the humerus (16.00 %). For the femur, the proportion is 28.00 %, and for the forearm, it is 20.00 %.

The treatment technology of anterograde bone transport was most commonly used for defects of the tibia — in 85.19 % of cases, and least frequently for fractures of the radius — 3.70 %. This method was not statistically significant in the treatment of patients with humeral bone defects.

Retrograde bone transport was only applied for long bone defects of the lower limb: in 75.00 % of cases for the tibia and in 25.00 % for the femur. It

was not performed in statistically significant volumes in the upper limb segments.

Surgical treatment technologies such as bifocal or trifocal lengthening of the limb, anterograde + retrograde bone transport, and acute shortening were only used for tibial bone defects (100 % in terms of proportion).

Length correction was most commonly applied for distal bone defects of the lower limb — 55.56 %, for the femur — 33.33 %, and only 11.11 % for the radius. Thus, this technique was used in 88.89 % of cases for lower limb segments.

Bone plastic surgery was used in 25.00 % of cases for humeral defects and in 75.00 % for large tibial defects.

Therefore, the Masquelet technique is more universal and can be used for large defects of various limb segments, whereas most other methods have much narrower applicability, limited to specific areas.

After conducting a polychoric analysis of the data in Table 3, a positive ($\varphi^2 = 0.3381$), very strong ($C = 0.5027$), and statistically significant ($\chi^2 = 31.11$) correlation was found between the types of surgical treatment and the segment of the limb affected by the defect. These data fall within the confidence field.

Thus, it can be concluded that the application of surgical treatment technologies for long bone defects is significantly dependent on both the "upper-lower" limb and "distal-proximal" segment classification.

Discussion

The results of this study indicate a variety of technologies used during surgical interventions for patients with long bone defects caused by modern combat injuries. Both modern techniques like Masquelet and traditional methods like bone transport are employed.

Comparisons with global literature suggest that Masquelet is more commonly used abroad for combat injuries [9, 10]. However, this comparison cannot be considered entirely accurate due to the unique scope and nature of limb injuries in modern combat operations in Ukraine, particularly in terms of the medical assistance provided.

A significant advantage of our study is the detailed investigation of the application of technologies based on the localization of bone defects in different segments of the limbs. While such studies have been conducted abroad, they have been limited to specific methods of surgical treatment [11, 12].

In open and accessible sources of scientific information, we did not find data on the use of surgical treatment technologies for long bone defects due to modern combat injuries based on limb segments in statistically significant volumes [13–15]. Our research has proven that the choice of a particular intervention for bone defects caused by combat trauma is significantly dependent on the affected segment. At the same time, it should be noted that only Masquelet was used to treat defects in all limb segments. Additionally, we established the predominant use of the Masquelet technique for upper limb defects. It was found that this method was mostly used for proximal segments of both the upper and lower limbs.

Bone transport was virtually not applied to the proximal upper limb, and retrograde bone transport was not used for the upper limbs. Furthermore, techniques such as bifocal and trifocal lengthening and acute shortening of bones were not used, but bone plastic surgery was relatively widely applied to the proximal upper limb segment. On the other hand, the preferred method for surgical treatment

Table 3

Distribution of the cohort of patients in groups by treatment method based on the injured segment

Technology	Shoulder	Forearm	Hip	Tibia	Total
	percentage (%)				
Masquelet	16.00	20.00	28.00	36.00	100
Anterograde bone transport	0	3.70	11.11	85.19	100
Retrograde bone transport	0	0	25.00	75.00	100
Anterograde + retrograde bone transport	0	0	0	100.00	100
Bifocal limb lengthening	0	0	0	100.00	100
Trifocal limb lengthening	0	0	0	100.00	100
Bone grafting	25.00	0	0	75.00	100
Length correction	0	11.11	33.33	55.56	100
Acute shortening	0	0	0	100.00	100

of upper limb defects and proximal lower limb defects is Masquelet, while for distal lower limb defects, the preferred method is anterograde bone transport. It is important to note that all surgical intervention technologies were used exclusively for treating bone defects in the distal lower limb segment. The analysis of open sources did not allow us to explain these facts with certainty. This requires detailed and thorough investigation, the results of which will be shared in our future scientific publications.

Conclusions

The technologies for treating long bone defects due to modern combat trauma are diverse and include both innovative and classical approaches. The Masquelet technique is the most commonly applied method for surgical treatment of patients with long bone defects of the upper limb and proximal segment of the lower limb caused by modern combat trauma, while anterograde bone transport is used for the distal segment of the lower limb.

The use of a specific surgical technology for treating bone defects due to modern combat trauma is likely dependent on the segment of the injury. Further thorough studies are required to reliably explain this fact.

Conflict of Interest. The authors declare that there is no conflict of interest.

Prospects for Further Research. Future studies will aim to analyze the use of specific surgical technologies for treating bone defects caused by modern combat trauma, depending on the size of the defect.

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APPLICATION OF SURGICAL TECHNOLOGIES FOR THE TREATMENT OF VICTIMS WITH LONG BONE DEFECTS DUE TO MODERN COMBAT TRAUMA

S. Guryev [1], S. Hariyan [2], V. Kushnir [1], O. Tsybulsky [2]

[1] SI «Ukrainian Scientific and Practical Center for Emergency Care and Disaster Medicine of the Ministry of Health of Ukraine», Kyiv

[2] MI «Ternopil Regional Clinical Hospital». Ukraine

✉ Serhiy Guryev, MD, Prof.: gurevsergej1959@gmail.com; https://orcid.org/0000-0003-0191-945X

✉ Serhiy Hariyan, MD, PhD: drhariyan@gmail.com; https://orcid.org/0009-0006-2662-5756

✉ Vitalii Kushnir, MD, DMSci: kv78@i.ua; https://orcid.org/0000-0003-4569-7246

✉ Oleksandr Tsybulsky: tsybulsky.oleksandr@gmail.com; https://orcid.org/0009-0009-5310-3621