

STAGED REHABILITATION OF MILITARY PERSONNEL AS PART OF A MULTIMODAL APPROACH TO THE GUNSHOT SOFT TISSUE DEFECTS RECONSTRUCTION

Igor A. Lurin^{1,2}, Igor P. Khomenko², Olena A. Gozhenko³, Volodymyr V. Nehoduiko^{4,5}, Oleh S. Herasimenko⁶, Serhii V. Tertyshnyi⁶, Evgeny O. Grigoriev⁷

¹NATIONAL ACADEMY OF MEDICAL SCIENCES OF UKRAINE, KYIV, UKRAINE

²STATE INSTITUTION OF SCIENCE «RESEARCH AND PRACTICAL CENTER OF PREVENTIVE AND CLINICAL MEDICINE» STATE ADMINISTRATIVE DEPARTMENT, KYIV, UKRAINE

³SE «UKRAINIAN RESEARCH INSTITUTE OF TRANSPORT MEDICINE» OF THE MINISTRY OF HEALTH OF UKRAINE, ODESA, UKRAINE

⁴MILITARY MEDICAL CLINICAL CENTER OF THE NORTHERN REGION, KHARKIV, UKRAINE

⁵KHARKIV NATIONAL MEDICAL UNIVERSITY, KHARKIV, UKRAINE

⁶MILITARY MEDICAL CLINICAL CENTER OF THE SOUTHERN REGION, KHARKIV, UKRAINE

⁷INTERNATIONAL EUROPEAN UNIVERSITY, KYIV, UKRAINE

ABSTRACT

Aim: To increase the efficacy of the original staged scheme of wounded with soft tissues gunshot defects (STGD) rehabilitation using the original improvement of diagnostic and restorative rehabilitation measures.

Materials and Methods: The wounded with STGD were admitted to the Military Medical Clinical Center of the Southern Region (Odesa). The wounded were randomized in three groups depending on the severity of the injury for further rehabilitation in sanatorium-resort conditions. Spectral infrared thermography diagnostic capabilities were used to control the efficacy of rehabilitation measures and to evaluate the rehabilitation prognosis.

Results: The data obtained were divided into immediate clinical and delayed organizational ones with rapid implementation into the medical practice to support the military forces of Ukraine. Authors showed the full-fledged functional recovery of the patient's injured limbs as a result of original step-by-step scheme applying of providing medical care in cases of STGD.

Conclusions: Timely rehabilitation measures at all stages of providing medical care in the Armed Forces are faster and more effective. The organizational and methodological foundations of the staged rehabilitation system of wounded servicemen with STGD at different levels of medical care depending on the severity of the injury and the tactics of surgical treatment have been developed. Different three- and four-staged models of rehabilitation measures for the injured with different severity have been proposed.

KEY WORDS: soft tissues gunshot defects reconstruction, surgical treatment, staged rehabilitation, treatment efficacy, rehabilitation, multimodal concept

INTRODUCTION

Rehabilitation of military personnel after lower extremities soft tissue gunshot wounds defects is a common and challenging problem for surgical and rehabilitative teams [1]. The process of soft tissues gunshot defects (STGD) reconstruction is multi-staged and requires a number of operative interventions in different periods of time at different levels of medical care [2]. Rehabilitation measures for such patients are also different. Currently, medical assistance to military personnel is four-level. Each level has its own amount of medical assistance [2, 3].

The first level of medical support is formed and implemented at the tactical level for the expense of the battalion's medical service, forces and means and provides the first medical (pre-medical) and first medical aid.

The second level of medical support is formed and implemented at the tactical level for the expense of the brigade medical service, forces and means and provides the qualified medical assistance. Therefore, rehabilitative measures at the first and second levels are actually not provided, are not expedient and not of primary importance.

The third level of medical support is formed and implemented at the operational level for the expense of military mobile hospitals and stationary military or civilian health care facilities deployed within the operational zone, and provides the qualified and specialized medical care. At this level, rehabilitation assistance is provided in the acute period. If the goal cannot be achieved, the injured person is transferred to the fourth level of medical care.

The fourth level is formed and implemented at the strategic level for the expense of military medical clinical centers, state and communal health care facilities and provides the highly specialized medical care using high-tech equipment and/or high complexity specialized medical procedures. This level of medical support is the place where the goal and task of rehabilitation of the wounded must be fully realized. At this level, rehabilitation care is provided in acute, post-acute and postponed long-term rehabilitation periods in inpatient and outpatient conditions.

Rehabilitation measures in sanatorium-resort conditions in the post-acute and long-term rehabilitation periods of wounded servicemen are implemented exclusively in sanatorium-resort facilities of the Armed Forces [4] which include the sanatorium department of the Military Medical Clinical Center of the Southern Region.

Certain time we have been actively improving the medical and physiotherapeutic method of providing medical, including highly specialized, home care to victims with soft tissues gunshot wounds which provides an opportunity to report certain original ideas and achievements [3, 5].

AIM

The aim of the present work was to increase the efficacy of the original staged scheme of wounded with soft tissues gunshot defects rehabilitation using the original improvement of diagnostic and restorative rehabilitation measures.

MATERIALS AND METHODS

According to the statistical analysis of the nature of injuries in the wounded who were admitted to the Military Medical Clinical Center of the Southern Region (Odesa), in the structure of sanitary losses of the surgical profile, the specific weight of wounded with STGD is 16.7%.

The anatomical and functional characteristics of STGD localization were as follows: chest – 14.0%, abdomen – 7.0%, pelvis – 4.1%, limbs – 74.9%. In the STGD structure extra-large injuries made up 6.1%, large – 33.7%, medium – 60.2%.

Clinical-epidemiological and clinical-anatomical studies proved that 36.8% of STGD wounded had a mild combat surgical injury, 45.7% – severe, and 17.5% – extremely severe.

The cause of STGD in 45.6% of servicemen was shrapnel wounds, bullet wounds in 38.0%, mine-explosive wounds in 16.4%. Isolated combat surgical injury was found in 28.9% cases, multiple – in 44.2%, combined – in 26.9% of wounded with STGD.

Impenetrable combat surgical trauma was diagnosed in 62.9% of the wounded, penetrating into the pleural cavity – in 17.4%, into the abdominal cavity – in 16.3%, into the pelvic cavity – in 3.4% of servicemen.

Using the abovementioned statistical calculation, we randomized patients on the following three groups for further rehabilitation in sanatorium-resort conditions (Admission Trauma Scale (AdTS) index was used to assess the severity of injuries) [6]:

The 1st group – wounded with a mild injury (medium-sized STGD, AdTS <5 points, perfusion index >4%) after a full volume of surgical care with primary and final correction of the injury;

The 2nd group – wounded with severe trauma (large-sized STGD, AdTS 5-9 points, perfusion index 2-4%);

The 3rd group – wounded with extremely severe trauma (extra-large STGD, AdTS >9 points, perfusion index <2%).

Spectral infrared thermography diagnostic capabilities were used to control the efficacy of rehabilitation measures and to evaluate the rehabilitation prognosis.

RESULTS

For the 1st group wounded servicemen we developed a three-staged model of rehabilitation when the wounded began rehabilitation measures in the acute period in a hospital (stage I) and, upon reaching certain conditions, were immediately transferred to a specialized department of a sanatorium-resort facility (stage II with 21 days duration) and, if necessary, to the outpatient stage of rehabilitation (III stage with 14 days duration). Our diagnostic, clinical and rehabilitative measures optimization resulted in 94% wounded of this group return to military service after early sanatorium-resort rehabilitation.

We have proposed a four-staged model of rehabilitation for the wounded of the 2nd group. We propose to divide the sanatorium-resort rehabilitation stage (II stage) into an early sanatorium, which is provided in the post-acute rehabilitation period and, accordingly, consists of two parts (the stage of reconstructive surgical interventions with 10 days, and the stage after the final surgical reconstruction with 12-14 days duration), and delayed (not mandatory), which is provided in the long-term rehabilitation period, in particular, in cases of complications development, for example, scar contractures, keloid scars, etc.

The wounded of the 3rd group also received rehabilitation treatment according to the four-staged model. Their rehabilitation potential was additionally considered at the outpatient stage (III stage) and doctors of the military medical commission made decisions about the possibility of their further military service. The terms of such patients' referral to rehabilitation stages were longer.

We have diversified and optimized the inpatient stage of rehabilitation to make it more effective. We suppose to resolve the following problems on this stage: pain reduction; the inflammatory exudates volume reducing; tissues metabolic needs reduction; affected tissues protection from further damage; protection of tissues formed from tearing; ensuring the new tissue growth and fibers restoration; maintaining the cardiovascular and muscle-skeletal systems normal functional activity; infectious complications development preventing, etc.

Medication treatment is prescribed to prevent postoperative complications. The PRICE principle is applied for the patients in the early stages (up to 72 hours after surgical treatment) after soft tissue injuries management: Protection; Rest; Ice; Compression (to reduce the volume of exudates and pain); Elevation (to reduce bleeding, swelling, pain) [7].

2-3 days after the surgery (when the stage of tissue proliferation begins) we fulfilled the following tasks of rehabilitation: pain reduction; edema reduction; local temperature decreasing; further tissue damage prevention; newly formed tissues protection; muscle strength and

coordination both support and enhancement; the functions improvement.

We used a basic complex of therapeutic gymnastics (TG), breathing exercises in the initial position lying on the back is prescribed; the patient is verticalized. On the 3rd – 4th day the patient performs the basic TG complex and breathing exercises in the initial position lying on his back and sitting; sitting in bed with the lower limbs lowered from it, therapeutic dosed walking (TDW) with additional support (walkers, crutches) with limitation of axial load on the injured limb within the ward is allowed. Massage of the upper extremities is prescribed throughout the 4th till 5th day.

The basic TG complex is expanded due to the increase in repetitions, the duration of classes and the variety of the starting position. Exercises are prescribed to preserve the range of motion in the injured limb. The main limitation for expanding the range of active and passive movements is pain. The limitation of axial load on the injured limb is maintained.

It is important to assign physical loads along the functional load lines, which are normally characteristic of one or another tissue. This will contribute to the structuring of collagen fibers, which are aligned along the line of application of the load. Starting from the 6th day we allowed to increase the level of loads, which is due to the formation of a sufficiently large layer of fibrous tissue.

Physiotherapy treatment is extended by electrotherapy, laser therapy, etc. Psychotherapy sessions are also provided with the wounded.

While prescribing the hardware physiotherapy methods we used a syndromic-pathogenetic approach with the dominant functional disorders and syndromes identification that need to be affected: ultrasound therapy – for metabolism within improvement; neuroelectrostimulation and non-selective phototherapy – for trophic and local bloodflow in tissues improvement; local air cryotherapy – for pain decrease reduction of swelling and pain syndrome; low-intensity laser therapy – for tissue metabolism increasing.

At the long-term stage of rehabilitation, in particular with the formation of scar contractures, natural healing resources of sanatoriums and resorts are widely used, in particular balneotherapy with mineral waters (hydrogen sulfide, radon, etc.), hydrotherapy and thalassotherapy (sea bathing), peloid treatment.

Let us give a specific clinical case.

A patient C. was admitted to the surgical department with a diagnosis – fire penetrating bullet wound of the right knee joint. The right leg tibial bone proximal metaepiphysis fiery intraarticular fracture. Right leg peroneal nerve posttraumatic neuropathy. Traumatic shock of the II-III degrees.

We have been fulfilled.

1. Primary surgical treatment of the wound (Fig. 1-A). Fixation of a tibial bone fracture using rod device for limbs external fixation (RDLEF) (Fig. 1-B).
2. Multimodal monitoring (dynamic digital thermography, right leg soft tissues sonography at the level of the injury and surrounding soft tissues). The study was conducted

dynamically: before the operation once per day, after the operation – the 1st day 6 times a day, the 2nd day 4 times a day, the 3rd day 3 times a day (Fig. 1-C, 1-D).

3. Repeated surgical treatment of the wound defect and a controlled negative pressure system installation (Fig. 1-E, 1-F).
4. Repeated surgical treatment of the wound defect. The controlled negative pressure system dismantling. Wound defect reconstruction using a hybrid method (Key Stone + rotary flap) (Fig. 2-A).
5. The RDLEF dismantling 3 months after the injury (Fig. 2-B).
6. Physical exercise starting from the 4th month beginning (the first week after the RDLEF dismantling)

We provided constant monitoring according to the multimodal scheme after each session of therapeutic physical training and registered the temperature gradient increase after each session by $0.33 \pm 0.04^\circ\text{C}$ (Fig. 2-C, 2-D).

According to the results of surgical and rehabilitation treatment the supporting function of the limb is restored by 75%. The length is restored by 100% that is characterized by (a) active bending 70 degrees; (b) passive bending 65 degrees; (c) active and passive extension restored to 180 degrees.

Sensibility in the lower leg and foot has been restored by 70% (Fig. 2-E, 2-F, 2-G).

DISCUSSION

We divide our obtained data into immediate clinical and delayed organizational ones, which, at the same time, with rapid implementation into the medical practice of providing support to the military forces of Ukraine, will contribute to the development of a significant clinical effect.

The first most important block of obtained data convincingly testifies to the full-fledged functional recovery of the patient's injured limbs as a result of applying our original step-by-step scheme of providing medical care in cases of STGD. To the full functional recovery, we will add the critical importance of such a result for the functioning of the entire organism as a whole, for the symmetrical functioning of the contralateral leg, as well as the speed of obtaining a positive clinical result.

Let us add that this happened as a result of our many years of clinical improvement of surgical treatment tactics, optimization of diagnostic processes, and currently developing tactics of rehabilitation stages of treatment [8-11].

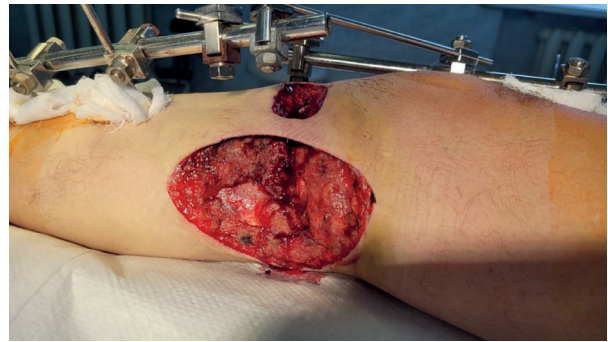
With regard to our proposals for the original staged scheme of medical care providing to victims with STGD, we allow ourselves to say the following.

Rehabilitation measures are provided at the third and fourth level of medical care. They are provided according to the available material and technical base of the health care facility where the injured person is staying, etc. At the same time, the provision of medical rehabilitation services in sanatorium-resort facilities of the Armed Forces of Ukraine, in our opinion, can be attributed to the fourth level [5].

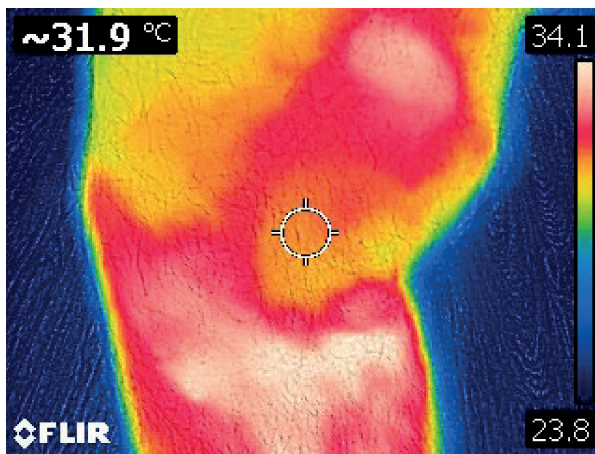
Rehabilitation measures in sanatorium-resort conditions in the post-acute and long-term rehabilitation periods



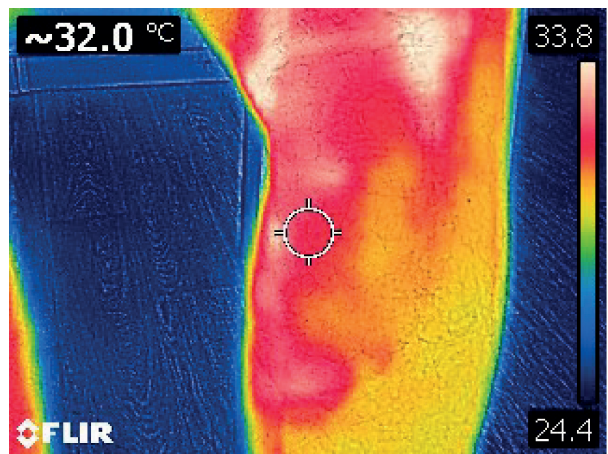
A – Primary surgical treatment of the wound;



B – Fixation of a tibial bone fracture using rod device for limbs external fixation;



C&D – dynamic digital thermography after the injury;



E&F – repeated surgical treatment of the wound and a controlled negative pressure system installation.



Fig 1. Diagnostic and treatment measures in patient C.

for wounded servicemen are implemented exclusively in sanatorium-resort facilities of the Armed Forces of Ukraine.

We suppose the transfer to a sanatorium for wounded persons is possible under the following conditions: (a) stable somatic condition; (b) self-service within the department; (c) satisfactory coagulogram indexes with hemoglobin level >100 g/l; (d) body temperature within normal limits; (e) removal of postoperative sutures, drains, satisfactory condition of the postoperative wound; (f) postoperative complications absence.

We propose to carry out the inpatient stage of rehabilitation in the acute and post-acute rehabilitation periods immediately after surgical treatment in a health care facility where

specialized or highly specialized surgical care was provided. It lasts the entire time of the injured person's stay in the hospital from the first hours after surgical treatment [3].

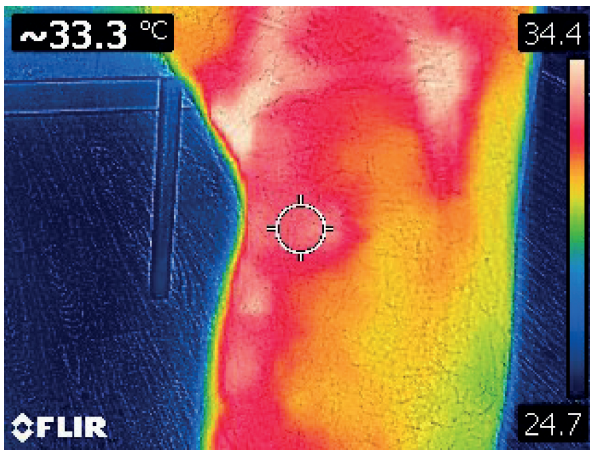
Resuming, one should mentioned the following. Timely rehabilitative measures at all stages of providing medical care in the Armed Forces, including sanatoriums, contribute to the reduction of hospital bed days, longer stay of the wounded under professional medical supervision, in particular at the stage of formation of a "skin patch", the number of complications reduction, including infectious ones at the stages of reconstructive and restorative surgical treatment and the formation of contractures at the long-term stage of rehabilitation [8, 12].



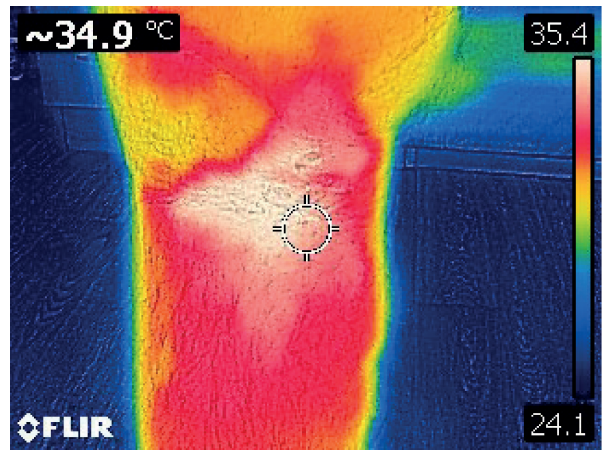
A. Wounded leg after gun-shot defect reconstruction using a hybrid method;



B – Wounded leg 3 months after the injury; the rod device for limbs external fixation is dismantled;



C&D – dynamic digital thermography after the physiotherapy sessions;



E, F&G – injured leg after a complex of therapeutic and rehabilitation measures

Fig 2. Medical and rehabilitation measures in patient C.

The dividing of early sanatorium-resort rehabilitation stage for the wounded with severe STGD depending on the staged surgical treatment is scientifically justified.

We believe that our medical success is due to various step-by-step models of rehabilitation measures that were proposed for the wounded with different degrees of severity. A three-step model of rehabilitation was developed for wounded persons with minor injuries. We proposed a four-stage model of rehabilitation for the wounded with severe trauma and the same four-stage model of rehabilitation we proposed for the wounded with extremely serious injuries.

CONCLUSIONS

1. Timely rehabilitation measures at all stages of providing medical care in the Armed Forces are faster and more effective.
2. The organizational and methodological foundations of the staged rehabilitation system of wounded servicemen with STGD at different levels of medical care depending on the severity of the injury and the tactics of surgical treatment have been developed.
3. The early sanatorium-resort rehabilitation stage separation of patients with severe soft tissue injuries depending on the staged surgical treatment is scientifically justified. Groups of the wounded were allocated for rehabilitative treatment depending on their injury severity.
4. Different three- and four-staged models of rehabilitation measures for the injured with different severity are proposed.
5. A personalized approach to each wounded person is extremely important, taking into account his functional and clinical condition and based on the results of the rehabilitation examination.

References

1. Khomenko IP, Korol SO, Matviichuk BV et al. Khirurgichna taktyka likuvannya poranenykh z vohnepal'nymy poranennyamy stehna na vsikh rivnyakh medychnoho zabezpechennya. [Surgical tactics of treatment of the wounded with gunshot wounds of the thigh at all levels of medical support]. *Klinichna khirurgiia*. 2019;86(5):22-26. doi: 10.26779/2522-1396.2019.05.22. (Ukrainian)
2. Khomenko IP. Instruktsiya z medychnoho zabezpechennya Zbroynykh Syl Ukrainy na osoblyvyvy period [Instruction on medical support of the Armed Forces of Ukraine for a special period]. Kyiv: Kyiv : Liudmila Publishing House. 2019, p.192. (Ukrainian)
3. Khomenko IP, Gumenyuk KV, Korol SO et al. Change Of the Concept of Surgical Support For Wounded With Soft Tissue Defects at the Levels Of Medical Care. *International Journal Dental and Medical Sciences Research*. 2022;4(1): 351-354.
4. Babova IK, Rozhkov VS. Sanatorno-kurortna reabilitatsiya viys'kovosluzhbovtziv v Ukraini: publichno-upravlins'kyi aspekt [Sanatorium-resort rehabilitation of military personnel in Ukraine: public-management aspect] *Publichne upravlinnya i administruvannya v Ukraini*. 2020;19:21-26. doi: 10.32843/pma2663-5240-2020.19.4. (Ukrainian)
5. Babov KD, Khomenko IP, Tertyshnyi SV et al. Orhanizatsiya etapnoyi reabilitatsiyi viys'kovosluzhbovtziv z vohnepal'nymy defektamy m'yakykh tkanyh na rivnyakh nadannya medychnoyi dopomohy [Organization of staged rehabilitation of servicemen with gunshot defects of soft tissues at the levels of providing medical assistance]. *Socialna Medycyna*. 2021;4:188-195. doi: 10.26641/2307-0404.2021.4.248228. <https://repo.odmu.edu.ua:443/xmlui/handle/123456789/11336> [date access 21.06.2023]. (Ukrainian)
6. Denysenko VM, Baramiya NM, Korol' SO et al. Otsinka tyazhkosti travmatychnoho shoku ta vybir khirurgichnoyi taktyky pry poyednaniy abdominal'niy travmi [Assessment of the severity of traumatic shock and the choice of surgical tactics in combined abdominal trauma]. *Aktual'ni problemy suchasnoyi medytsyny: Visnyk ukrayin's'koyi medychnoyi stomatolohichnoyi akademiyi*. 2008;1-2(21-22). <https://cyberleninka.ru/article/n/otsinka-tyazhkosti-travmatichnogo-shoku-ta-vibir-hirurgichnoyi-taktiki-pri-poednaniy-abdominalniy-travmi> [date access 05.07.2023]. (Ukrainian)
7. Bleakley CM, O'Connor S, Tully MA et al. The PRICE study (Protection Rest Ice Compression Elevation): design of a randomised controlled trial comparing standard versus cryokinetic ice applications in the management of acute ankle sprain. *BMC Musculoskelet Disord*. 2007;8:125. doi: 10.1186/1471-2474-8-125.
8. Lurin IA, Khomenko IP, Khoroshun EM et al. Klinichnyy vypadok vykorystannya kontseptsiyi monitorynhu pry likuvanni vohnepal'noho defektu m'yakykh tkanyh kolinnoho suhloba [A clinical case of using the concept of monitoring in the treatment of a gunshot defect of the soft tissues of the knee joint]. *Medichni Perspektivi*. 2023;2:197-207. doi: 10.26641/2307-0404.2023.2.283427. <https://repo.odmu.edu.ua:443/xmlui/handle/123456789/13366> [date access 21.06.2023]. (Ukrainian)
9. Khomenko IP, Tertyshnyi SV, Vastyanov RS et al. Soft tissues gunshot defects ultrasound investigation use in reconstructive-restorative surgery. *World of Medicine and Biology*. 2021;3(77):169-174. doi: 10.26724/2079-8334-2021-3-77-169-174.
10. Khomenko IP, Tertyshnyi SV, Vastyanov RS et al. Experimental background of thermometry using with diagnostic purposes in soft tissue gunshot damages. 2022. <https://repo.odmu.edu.ua:443/xmlui/handle/123456789/11323> [date access 21.06.2023]
11. Khomenko IP, Lurin IA, Nehoduiko VV et al. Soft tissue perfusion evaluation algorithm in the scheme of gunshot defects "closure". *Svit Medycyny ta Biologii*. 2023;1(83):169-173. doi: 10.26724/2079-8334-2023-1-83-169-173. <https://repo.odmu.edu.ua:443/xmlui/handle/123456789/12391> [date access 21.06.2023].
12. Khomenko IP, Tsema EV, Shapovalov VYu et al. Vykorystannya povnosharovoho klapyta za metodykoyu Keystoun pry rekonstruktsiyi peredn'oyi cherevnoyi stinky (klinichne sposterzhennya) [The use of a full-layer flap according to the Keystone technique in the reconstruction of the anterior abdominal wall (clinical observation)]. *Khirurgiia Ukrainy*. 2019;3:65-70. doi: 10.30978/SU2019-3-65 <https://repo.odmu.edu.ua:443/xmlui/handle/123456789/10366> [date access 21.06.2023]. (Ukrainian)

The work is fragments of scientific-research investigation "Development of modern methods of diagnosis and treatment of purulent-septic complications in combat surgical trauma", state registration No 0120U101834.

ORCID AND CONTRIBUTIONSHIP*

Igor A. Lurin: 0000-0001-6280-1725^{A,F}
Igor P. Khomenko: 0000-0002-8199-5083^{A,E,F}
Olena A. Gozhenko: 0000-0002-4071-1304^{B,D}
Volodymyr V. Nehoduiko: 000-0003-4540-5207^{C,F}
Oleg S. Herasimenko: 0000-0002-0039-5757^{A,B}
Serhii V. Tertyshnyi: 0000-0002-4949-5409^{D,E}
Evgen O. Grigoriev: 0009-0004-4577-2511^{C,E}

ADDRESS FOR CORRESPONDENCE

Serhii V. Tertyshnyi
Military Medical Clinical Center of the Southern Region
2 Pirogovska st., 65044 Odesa, Ukraine
e-mail: tertyshnyi.sergey@gmail.com

CONFLICT OF INTEREST

The Authors declare no conflict of interest.

RECEIVED: 21.06.2023

ACCEPTED: 19.09.2023



***Contribution:**

A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review,
F – Final approval of the article