I-EDU GROUP

MSU

Article

The role of regional lymphatic therapy in gunshot wounds of the extremities

Mirzayev Kamal *[1]

[1] Department of Surgical Diseases and Civil Defense, Andijan State Medical Institute, Andijan, 170100, Uzbekistan kamalmirzaev1958@gmail.com (M.K.)

* Correspondence: kamalmirzaev1958@gmail.com (M.K.)

Abstract: Cases of gunshot wounds of the extremities are increasing every year in the Republic of Uzbekistan and other countries of the world. The urgency of this problem is justified by the high rates of death, purulent-septic complications, and disability, especially given the progress in the development of new types of weapons with greater penetrating power. The purpose of this study was to conduct experimental regional lymphatic treatment and use the results of the protocol to manage patients with isolated and combined gunshot wounds of the extremities. To achieve the goal of the study, 169 patients with gunshot wounds of the extremities were examined and divided into four main groups receiving lymphotherapy and control subgroups receiving standard treatment. In experimental studies, gunshot wounds of the extremities on the first day after injury are characterized by volumetric swelling of the intercellular space with the accumulation of microbes and deposition of fibrin, cellular dentin, and necrobiosis products in the lymph nodes. The use of regional lymphatic therapy in the experimental groups showed an active and rapid process of soft tissue regeneration in the traumatized area compared to that in the control group. Timely sorting and transportation of the wounded to specialized medical institutions contributed to the high effectiveness of surgical and therapeutic treatment methods in the first hours after the injury. The use of lymphotropic antibiotic therapy with cephalosporins or aminoglycosides and lymphatic stimulation showed positive dynamics of connective tissue remodelling, consistently high and long-term concentration of drugs in the lymph nodes, and low rates of infectious complications. The data obtained can be used in military medicine, emergency medicine, and surgery to improve protocols for managing patients with gunshot wounds of the extremities and the introduction of tactics aimed at preserving the functionality of regional tissues and preventing infectious complications.

Keyword: Tissue remodelling, antibiotic therapy, lymphatic drainage, military surgery, primary surgical treatment, wound healing.

Quoting: Mirzayev Kamal. The role of regional lymphatic therapy in gunshot wounds of the extremities. **2026**, 5, 1, 5. https://doi.org/10.56121/MSU-2026-1-00005

Received: 20.12.2025
Corrected: 18.01.2026
Accepted: 16.02.2026
Published: 2702.2026

Introduction

In modern realities, the tactics of treating gunshot wounds are topical issues in the fields of military medicine, infectious diseases, public health, and rehabilitation. Baum et al. presented a scientific review of gunshot wounds [1]. The prevalence of gunshot limb injuries and associated deaths is increasing in the United States according to R. Goel et al. [2] and in European and Asian countries according to Y. Wang et al. [3], improving the tactics of treating gunshot wounds are becoming more relevant for surgeons and emergency physicians. According to statistics, the number of gunshot injuries during local military conflicts, which lead to the death of the victim at the epicentre of the event, will stop more than half of the cases, while during medical treatment – more than 60% of cases [4,5]. In the Republic of Uzbekistan, mortality from penetrating wounds is almost 60%, and the number of cases of gunshot wounds, especially combined types, in the Republic is growing every year, leading to inflammatory and infectious complications, such as peritonitis and mediastinitis [6–8]. Thus, the relevance of the treatment of gunshot wounds is determined by the increasing rates of incidents (of a social and military nature), the high mortality rate of victims, and the threat of infectious complications, which also threaten the lives of patients.

Existing protocols for the management of patients with gunshot wounds are often outdated as they are drawn up in the absence of high-velocity weapons and deformable bullets [9]. The technological sophistication in the development of improved versions of firearms and the availability of their acquisition have exacerbated the picture of domestic injuries and terrorist conflicts. Considering the high mortality rates within the first hour after patients were injured in Uzbekistan, compliance of the quality of medical care with the current state of the technical component of weapons becomes critical [7]. Moreover, these factors complicate doctors' work in terms of making urgent decisions. during the provision of primary and specialized care [10,11]. The current state of the problem requires evidence-based approaches to improve military field tactics to successfully treat gunshot wounds of varying severity, considering the modern characteristics of weapons, the time limit for transportation, the provision of emergency medical care, and the mass nature of injuries in social or military conflicts.

The increased interest in gunshot wounds is also associated with the not-always-favorable conditions of the medical and tactical situation, according to the experience of military surgery, which greatly complicates the process of sorting the wounded and the timeliness of their transportation to the hospital [12,13]. That is, the development of improved tactics for the provision of medical care with gunshot wounds should take into account the real conditions during terrorism and civil confrontations and be effective even in limited time, technical conditions, and massive damage.

According to R. Omid et al., gunshot injuries are clinically characterized by volumetric and prolonged swelling of the subcutaneous tissue and regional soft tissues, which in turn creates conditions for microbial invasion, accumulation of toxic metabolites and decay products [14]. In addition to invasion, the microvasculature is subjected to compression [15]. According to morphological studies by Hlavaty et al., exudate accumulates in the intercellular space of the fascia, hypodermis, and along the edges of the wound zone, which exerts mechanical pressure on the blood vessels [16]. Thus, there is a need to develop additional methods of complex treatment that will be aimed at restoring the homeostasis of the tissues of the affected areas, compensating for the deficiency of circulation and lymphatic drainage, and improving the physiological characteristics of regional tissues in the wounded area.

Given the relevance of the treatment of gunshot wounds and the existing need to develop new complex methods of treatment, this study aimed to conduct an experimental therapy for gunshot wounds in the form of regional lymphatic treatment to improve the tactics of emergency and planned medical care for injured patients.

Materials and Methods

The scientific study was carried out at the Department of Hospital and Faculty Surgery of the Andijan State Medical Institute on the basis of the approved topic of the scientific work of the department. The cohort of patients participating in the study included 169 patients with gunshot wounds in the upper and lower extremities. After obtaining the consent of the patients to participate in scientific work, the total number of victims was divided into four groups. The distribution and composition of participants were randomized and random and depended on the medical and tactical situation, the nature of the triage of victims, and the intensity of admission or referral from other medical institutions. In each group of participants, the diagnosis included an assessment of the nature and extent of the injuries, indicators of the general condition, and the presence of complications from vital functions. In each of the four groups, patients were divided into a group receiving regional lymphatic therapy and a control group, in which treatment was carried out according to approved protocols of care without the use of lymphatic treatment.

The first group (I) consisted of 59 participants with isolated injuries of the soft tissues of the upper and lower extremities, 40 of whom underwent regional lymphatic therapy and 19 underwent standard therapy. The second study group (II) included 31 patients with gunshot fractures of the bone tissue but without volumetric soft-tissue defects. In the second group, 16 patients received experimental treatment, whereas 15 received standard treatment. The third study group (III) consisted of 42 patients with gunshot bone fractures and extensive soft-tissue injuries. In the third group, 26 patients received regional lymphatic treatment and 16 received standard treatment. In the fourth (IV) group of patients with gunshot injuries of the extremities, systemic infectious complications

were observed. The total number of patients in group IV was 37, 12 of whom formed the control subgroup, while 25 received experimental lymphatic treatment.

The applied regional lymphatic treatment was carried out by local activation of the lymphatic drainage function in order to reduce the volume of tissue swelling in the area of the injuries received and lymphotropic antibiotic therapy. Technically, lymphatic therapy was performed using a subcutaneous injection of a solution of 16-32 active units of lidase in 0.5% 20.0 volume) novocaine. The solution was injected by paramedics on the back surface of the hands or feet depending on the nature of the injury. The next step was the introduction of heparin at the same access point, with the calculation of 70 active units of the drug per 1 kg of body weight. The hourly interval between injections of drugs was 5-6 minutes, without changing the position of the needle. After the introduction of heparin, the needle was pulled outward (0.5 cm), followed by introduction of a third-generation antibiotic (depending on the clinical case). The antibiotic was administered once a day for a week, sometimes for 8 days.

For evidence-based assessment of the effectiveness of the applied therapy and assessment of the remodelling of damaged tissues in the experiment, histological examination was performed. Dark -field electron microscopy was used for additional visualization of regional lymphatic vessels and assessment of the histological integrity of the walls. The biopsy material of the study was represented by the tissues of the wound zone and regional lymph nodes (depending on the location of the wound). The tissue was fixed in 10% formalin solution for at least 24 h, dehydrated, placed in a solid medium (paraffin), stained with a combination of acid and basic dyes (hematoxylin and eosin), and placed on glass slides.

Results

The total cohort of the studied sample was represented by four groups of patients aged 17–60 years, mostly males (Table 1). The control subgroups always included fewer patients than did the experimental subgroups.

Table 1. Characteristics of the composition of the studied groups

Group	Gender of patients				Age of patients									
	Male		Female		17-20 years old		21-30 years old		31-40 years old		41-50 years old		51-60 years old	
	Main group		Control sub-group		Main group	Control sub-group	Main group	Control sub-group	Main group	Control sub-group	Main group	Control sub-group	Main group	Control sub-group
I	39	18	1	1	4	3	18	8	5	0	10	7	2	2
II	16	15	0	0	4	3	6	5	5	5	1	2	0	0
III	26	16	0	0	5	3	10	6	8	5	3	2	0	0
IV	25	12	0	0	4	2	8	3	8	4	4	2	1	1
Total	106	62	1	1	17	11	42	22	26	14	18	13	3	3

Most patients (73.4%) received primary care in time frames up to one hour, 14.2% up to two hours and 12.4% up to three hours from the time of injury (Table 2). Qualified medical assistance was mainly provided (64.8 %) during the first hour after injury. Specialized treatment was received by patients (21.8%) who were referred to the hospital from regional institutions from three hours to two days after traumatization (Table 2).

In the structure of the diagnoses of the examined, both gunshot wounds of the upper and lower extremities were observed with a predominance of isolated (43.2 %) injuries to the bones of the lower extremities (femur and lower leg – 10.6% and 21.4%, respectively) (Table 3). Isolated soft tissue injuries (38.4%) were observed more often in the thigh (13.0 %) and shoulder (10.0 %) and less often in the forearm (6.5%) and lower leg (8.9%). Multiple bone lesions were identified in 8.9% of the studies, whereas combined bone injuries were diagnosed in 9.5% of the cases. Among the combined types of gunshot wounds, damage to the limb and chest (3.5%) as well as combinations of injuries to the limbs and head (1.8%) or abdomen (1.8%) prevailed (Table 4).

Table 2. Characteristics of the subjects depending on the time and type of medical care received

Hospitalization term	Primary Care		Qualified medical care		Specialized medical care	
	Number	Percentage	Number	Percentage	Number	Percentage
Up to 60 minutes	124	73	24	64.8	100	59.2
Up to 120 minutes	24	14.2	8	21.6	19	11.2
Up to 180 minutes	21	12.4	5	13.6	13	7.8
From 3 hours to two days (delivered from other institutions)	0	0	0	0	37	21.8
Total	169	100	37	100	169	100

Table 3. The nature of the distribution of types of gunshot injuries to the extremities

Type of injury	Upper limb				lower limb				Total	
	Shoulder area		Forearm area		Thigh area		Calf area			
	n	%	n	%	n	%	n	%	n	%
Isolated soft tissue injuries	17	10	11	6.5	22	13	15	8.9	65	38.4
Isolated bone damage	10	5.9	9	5.3	18	10.6	36	21.4	73	43.2
Multiple bone injuries	3	1.8	4	2.4	3	1.8	5	2.9	15	8.9
Associated bone injuries	5	2.9	4	2.4	2	1.1	5	3	16	9.5
Total	35	20.7	28	16.6	45	26.6	61	36.1	169	100

Table 4. The nature of the combined types of gunshot injuries of the extremities, depending on the location

no	Type of combined injury	Absolute number	Percentage
1	Limb and head injury	3	1.8
2	Limb and chest injury	6	3.5
3	Limb and abdominal injury	3	1.8
4	Limb and pelvic injury	2	1.2
5	Limb and spinal injury	2	1.2
Total		16	

Surgical treatments were performed for each of the four groups (Table 5). Primary surgical care in the form of basic treatment with suture was performed in 48 cases, primary delayed suture was applied in 43 cases, and autodermoplasty in 34 cases. Surgical plasty of the wounds was performed in 13 patients. Osteosynthesis was also used: primary extramedullary in 31 cases and extrafocal in 42. Timely surgical treatment of the wound using lymphotropic antibiotic therapy allowed suturing in 66% of patients. Infectious complications were observed in only 2.5% of these patients.

In the experiment, the measurement of the concentration of the antibacterial drug in the regional lymph nodes showed that the standard treatment protocols did not provide a long-term therapeutic effect in the form of gentamicin concentration in the microcirculation and wounded area (Table 6). These data explain the prolonged period of tissue repair in the control group. The data of patients in the experimental groups who received lymphatic therapy with the introduction of antibiotics lymphotropically showed a long-term (24 h from the moment of administration) effect and the presence of drug concentration both in the area of the pathological process and in the lymphatic and bloodstream, which affects the quality of the development of the purulent-septic process, from the first day of treatment (Table 7).

Table 5. Characteristics of the studied patients depending on the applied methods of invasive treatment

Type of surgery	I		II		III		IV		Total (n=169)
	Main (n=40)	Control (n=19)	Main (n=16)	Control (n=15)	Main (n=26)	Main (n=26)	Main (n=25)	Control (n=12)	
Primary surgical dressing with suture	34	14	-	-	-	-	-	-	48
Primary delayed suture	4	2	-	-	7	4	19	7	43
Plastic reconstruction with local tissues	-	-	-	-	8	5	-	-	13
Autodermoplasty	3	2	-	-	9	9	6	5	34
Primary extramedullary osteosynthesis: - without autoplasty - with autoplasty	-		-	9, 7	10, 5	-	-	-	20, 11
Extrafocal osteosynthesis: - without autoplasty - with autoplasty	-	-	-	-	21, 5	13, 3	-	-	35, 7
Total number of interventions									211

Table 6. Indicators of the level of concentration of gentamicin in the regional lymph nodes after a single injection of the drug intramuscularly (control subgroup)

Localization	Time interval after drug administration (1 mg/kg)	
	6 hours	24 hours
Inguinal lymph nodes	Traces of the drug	Absent
Skeletal muscle tissue	Traces of the drug	Absent
Hypodermis	Traces of the drug	Absent

Table 7. Indicators of the level of concentration of gentamicin in soft tissues after a single injection of the drug lymphotropically (experimental group)

Localization	Time interval after drug administration (1 mg/kg)	
	6 hours	24 hours
Inguinal lymph nodes	2.25+0.27	1.02+0.22
Skeletal muscle tissue	0.55+0.13	0.2+0.06
Hypodermis	0.03+0.4	0.1+0.04

Surgical treatment of gunshot wounds in 24 patients resulted in complications in the form of infectious processes of the bone tissue, blood, and soft tissues (Table 8). Purulent-septic complications occurred in cases of late delivery of victims to the hospital for the provision of specialized medical care, the term of which also depended on the medical and tactical situation. Patients with purulent infectious complications were provided complex treatment with active monitoring of changes in the wound process, including bacteriological, cyto-, and histological studies, as well as the use of special imaging diagnostic methods. The use of the proposed lymphotropic antibiotic therapy in the protocols of patient management (Table 7) made it possible in many cases to cure complications in the form of surgical infection (Table 8) with a minimally invasive method of semi-closed therapy of purulent lesions.

By analyzing the histological picture of the biopsy material of loose fibrous tissue in the area of a gunshot wound in patients in the control subgroups, we can conclude several microscopic characteristics of soft tissue reactions to external injuries of this type. First, there was extensive swelling of the intercellular space (Figure 1) with accumulation of fibrin and cell dendrites (Figure 2). Second, the wounds were characterized by large areas of primary (in the early stages) and secondary

(Figure 2, several days later) tissue necrosis. Vessel stasis with lymphocytic infiltration was also observed (Figure 1).

Table 8. Characteristics of infectious complications of gunshot wounds of the upper and lower extremities, depending on the type of invasive methods used

Type invasive intervention	Total number of patients		Type of infectious complication											
	Main	Control	Suppuration				Osteomyelitis				Sepsis			
			Main		Control		Main		Control		Main		Control	
			N	%	N	%	N	%	N	%	N	%	N	%
Primary surgical treatment of wounds with sutures	40	19	1.0	2.5	2.0	10.5	0	0	0	0	1.0	2.5	1.0	5.2
Extramedullary osteosynthesis	16	15	1.0	6.2	3.0	20	1.0	6.2	2.0	13.3	0	0	1.0	6.6
Extrafocal osteosynthesis	26	16	2.0	7.7	3.0	18.5	1.0	3.8	2.0	12.5	1.0	3.8	1.0	6.2

The material of the control group showed that without the use of lymphatic treatment in the area of concussion, there was a violation of microcirculation, stasis of arterial and venous vessels, and necrotic changes without clear demarcation zones. The dark-field electron microscopy method (Figure 2) allows the visualization of thick, solid masses of fibrin in the intercellular space and fragments of microorganisms in the focus of an infectious lesion.

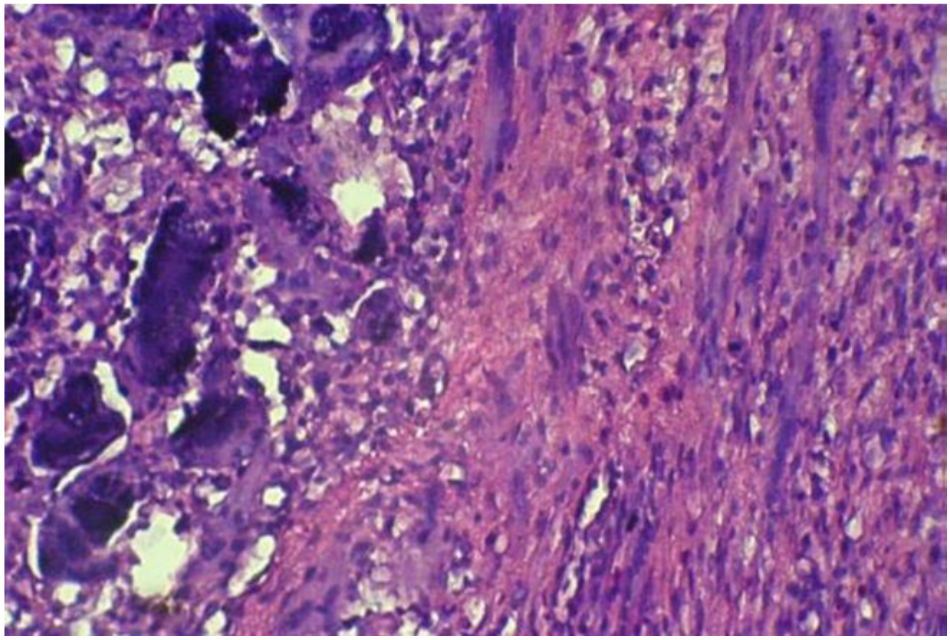

Figure 1. Histological micropreparation of soft tissues in the gunshot wound area on the third day after the wound. Control group. Haematoxylin and eosin staining. Magnification 10×16

The walls of the lymphatic capillaries in the later stages of the wound treatment process were thickened, with dilated lumens and stasis. (Figure 3). Along the boundaries of the commotional area, interstitial edema of loose fibrous tissue was observed, which increased when approaching the zone of necrotic masses. Fibrocytes and lymphocytes are also frequently observed. There was no cellular atypia.

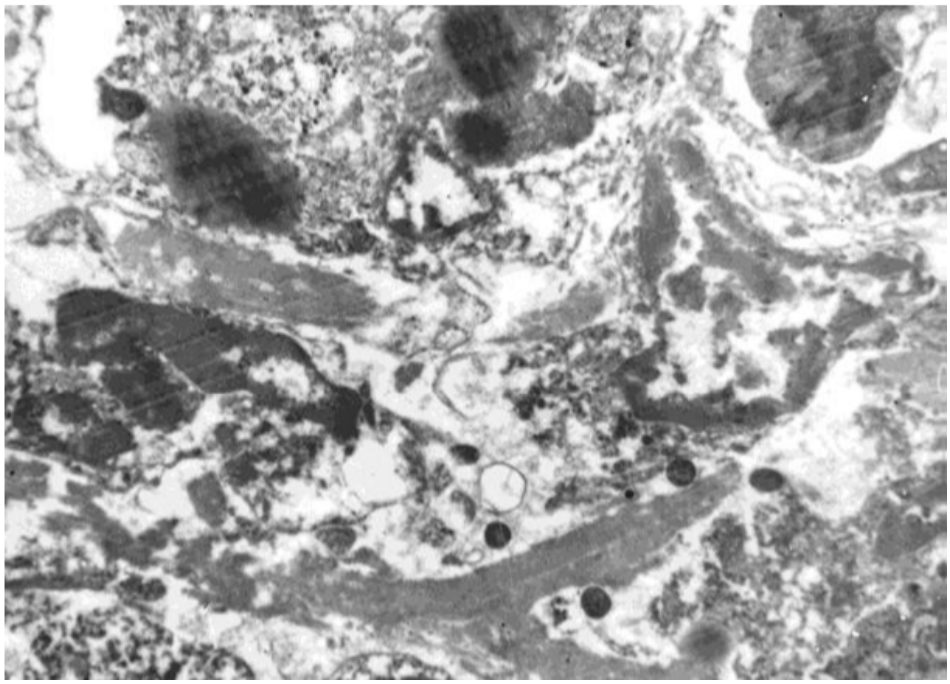

Figure 2. Dark-field electron micrograph of loose fibrous tissue in the area of the gunshot wound on the third day after the wound. Control group. Magnification x7500

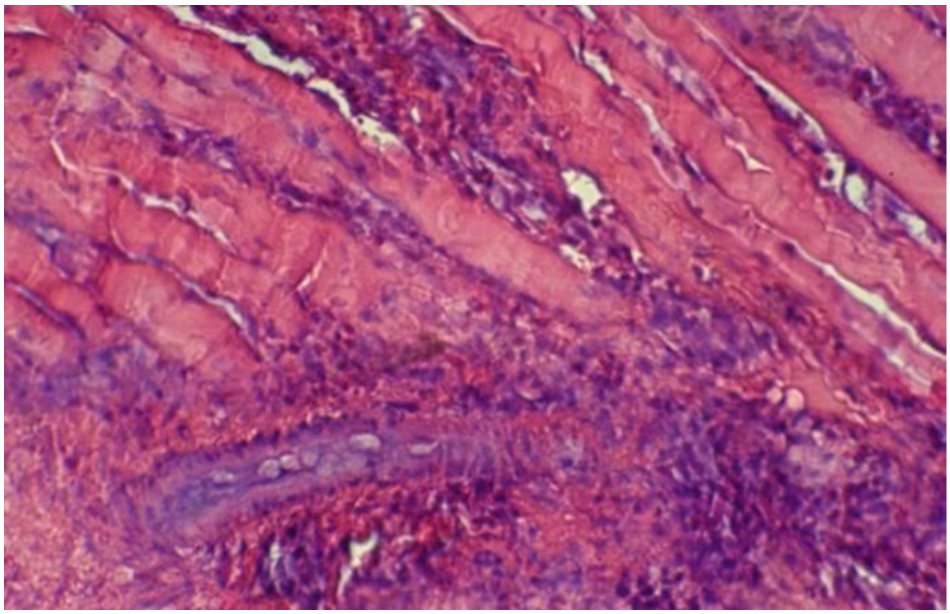

Figure 3. Histological micropreparation of soft tissues in the area of the gunshot wound on the fifth day after the wound. Control group. Haematoxylin and eosin staining. Magnification 10×16

The walls of the lymphatic capillaries in the wound area on the seventh day were characterized by a significant increase in the lumen without specific settlement structures (Figure 4). The endothelium is located in a solid ball, and the basement membrane is intact. The wall had increased permeability without an inflammatory reaction in the adventitia zone.

In some cases, in addition to changes in the properties of the lymphatic capillary walls, atypical cells were also observed, which were absent at earlier stages of the disease (Figure 5). Giant cells of foreign bodies with severe basophilia of the cytoplasm and multiple nuclei against the background of edematous loose tissue. Zones of secondary necrosis were represented in this case by necrotic skeletal myocytes and myosatellitocytes.

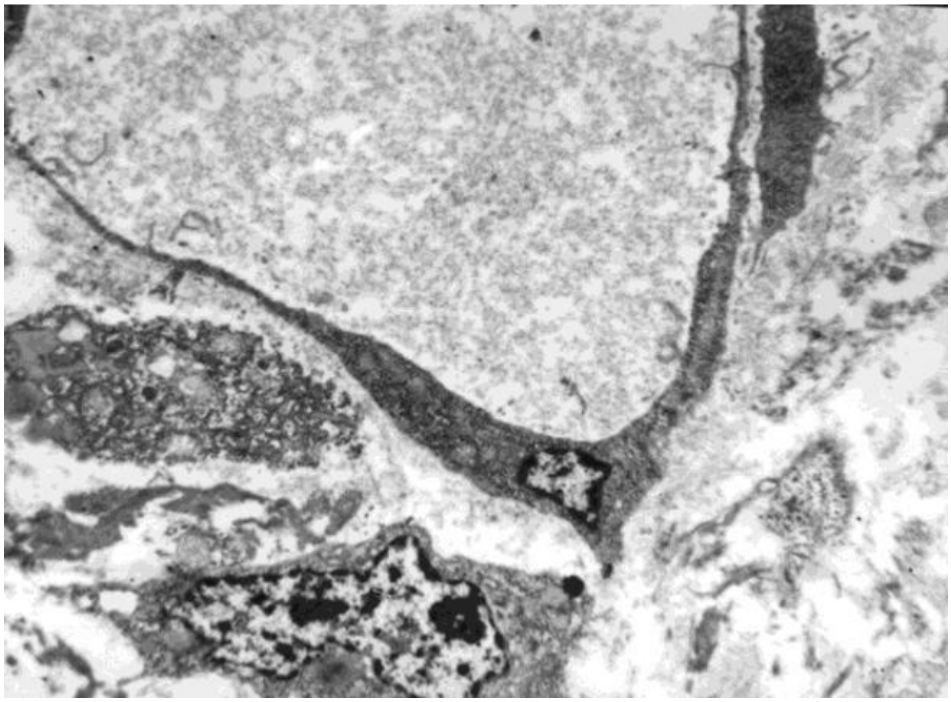

Figure 4. Dark-field electron micrograph of a lymphatic capillary in the area of a gunshot wound on the seventh day after the wound. Control group. Haematoxylin and eosin staining. Magnification x7500

In some cases, in addition to changes in the properties of the lymphatic capillary walls, atypical cells were also observed, which were absent at earlier stages of the disease (Figure 5). Giant cells of foreign bodies with severe basophilia of the cytoplasm and multiple nuclei against the background of edematous loose tissue. Zones of secondary necrosis were represented in this case by necrotic skeletal myocytes and myosatellitocytes.

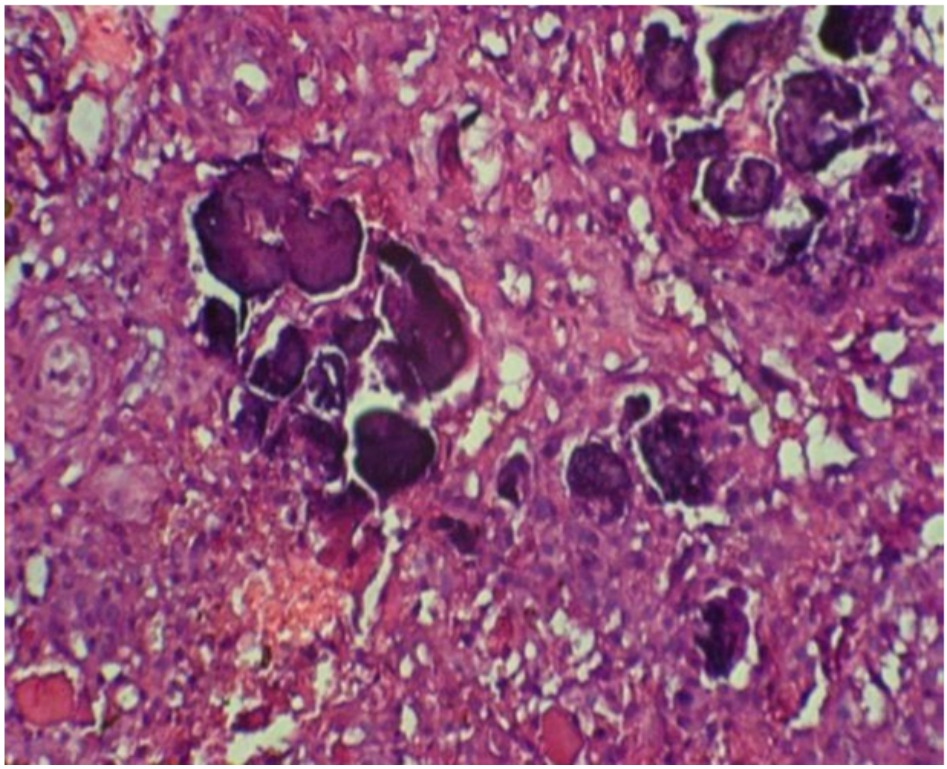

Figure 5. Histological micropreparation of soft tissues in the area of the gunshot wound on the fifth day after the wound. Control group. Haematoxylin and eosin staining. Magnification 10×16

In the experimental group of patients who underwent regional lymphatic antibiotic therapy, there was a decrease in interstitial edema on the fifth day of treatment (Figure 6). The walls of the lymphatic capillaries in the wounded area had a normal configuration with an enlarged lumen. Remodelling of damaged tissues in patients receiving special treatment was histologically observed on the seventh day (Figure 7), including neovasculogenesis (Figure 8).

Despite the presence of isolated or combined types of limb injuries in the experimental group, a decrease in swelling was observed on days 6-7 (Figure 8) with a decrease in the amount of cellular dentin in the amorphous substance. Neovasculogenesis was observed in the remodelled areas of the former secondary necrosis. Skeletal muscle fibers were remodelled due to myosatelitocytes with a normal configuration of muscle fibers and contractile myofibrils. New vessels of the microvasculature were characterized by a thin wall, small lumen, and continuous exposure of endotheliocytes.

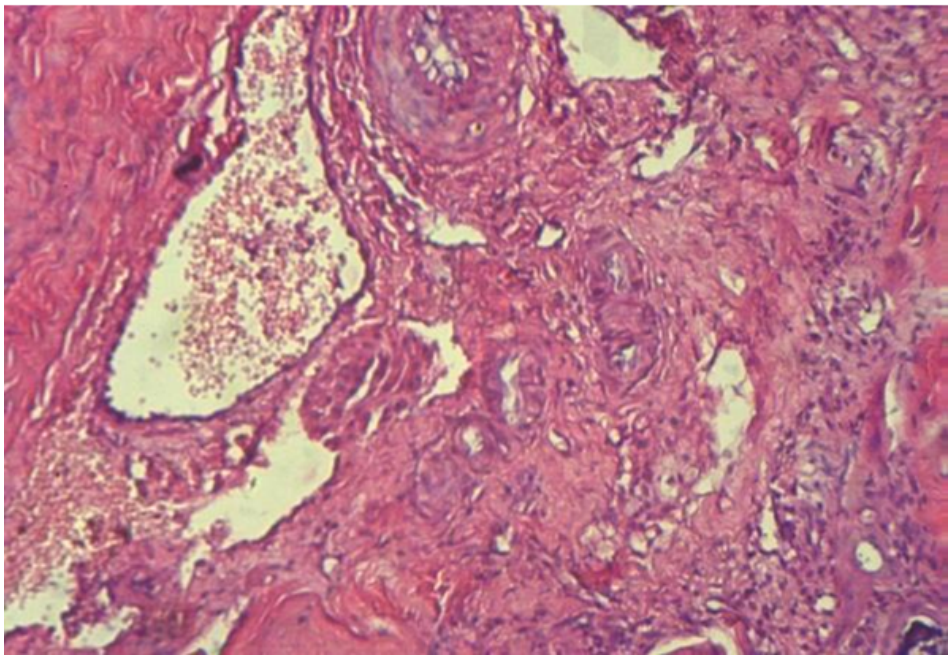

Figure 6. Histological micropreparation of soft tissues in the area of the gunshot wound on the fifth day after the wound. Experimental group with lymphotherapy. Haematoxylin and eosin staining. Magnification 10×16

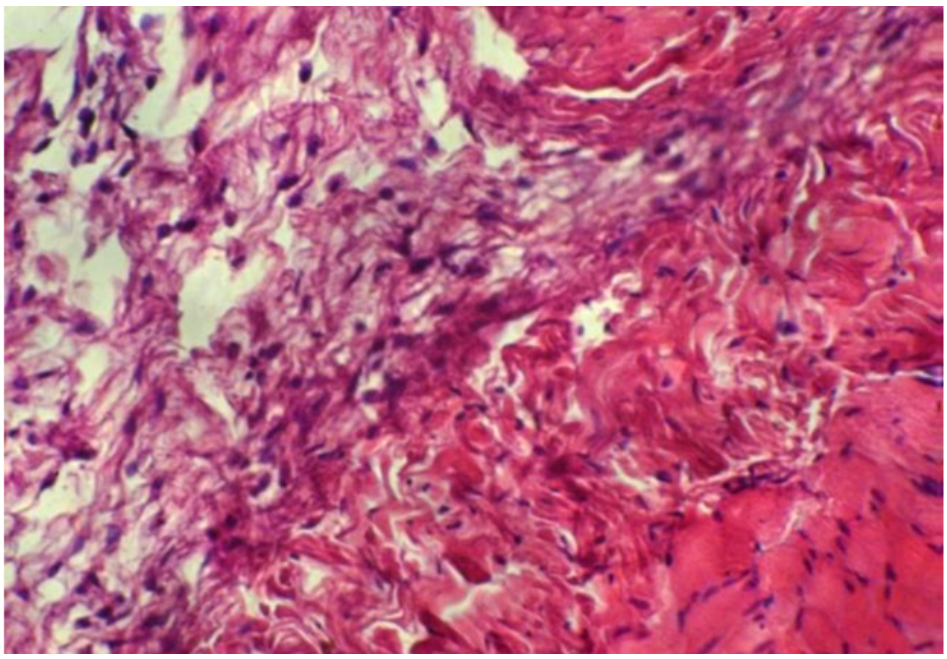

Figure 7. Histological micropreparation of granulation tissue on the seventh day after injury. Control group. Haematoxylin and eosin staining. Magnification 10×16

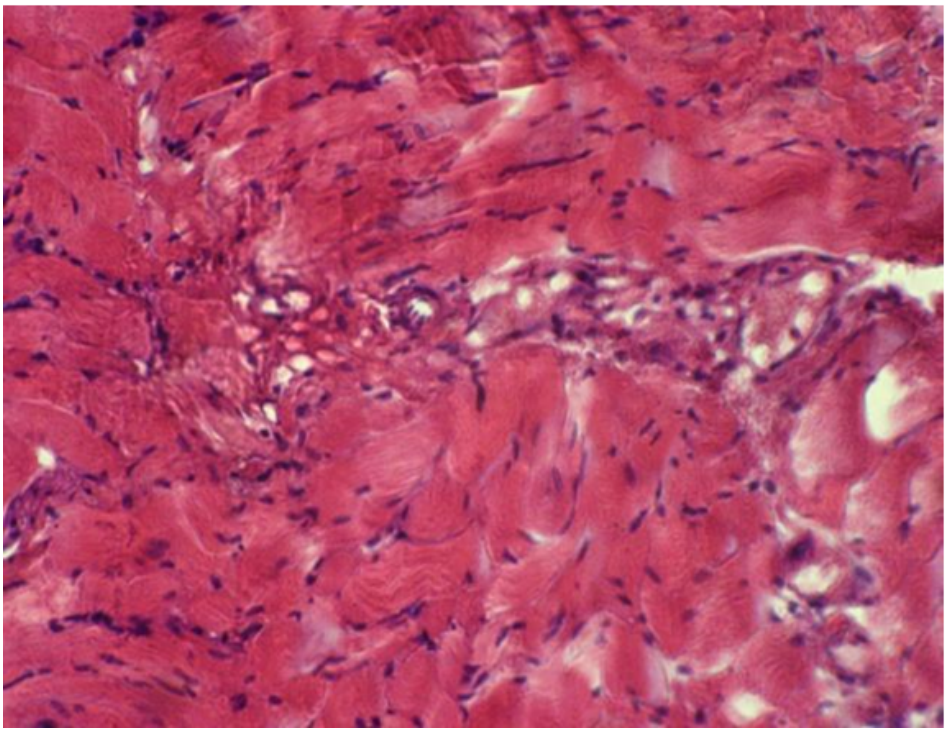

Figure 8. Histological micropreparation of granulation tissue on the seventh day after injury. Experimental group with lymphotherapy. Haematoxylin and eosin staining. Magnification 10×16

Discussion:

A scientific and practical study showed the presence of several characteristic signs of the course of gunshot wounds of the extremities from a pathophysiological and morphological point of view, especially with the use of lymphatic therapy. The results obtained showed the effectiveness of several components in the tactics of primary and specialized management and treatment of patients with isolated and combined types of injuries.

First, emergency transportation of the victim to a medical facility for the provision of specialized surgical care in the form of plastic reconstruction, suturing, and osteosynthesis. In this study, almost 22% of the patients were admitted to the hospital within an hour interval from three hours to two days after receiving isolated or multiple injuries, which in all cases under study required specialized medical care. Complications in the form of sepsis, osteomyelitis, and suppuration occurred with untimely and inadequate therapy (in some cases, control subgroups) and more often with combined injuries, as shown in the results. A seven-year retrospective study by J. K. Maddry et al. shows that in addition to the complications of gunshot wounds of the extremities studied in line work, timely transportation of the wounded to specialized medical institutions affects the timeliness of diagnosing traumatic compartment syndrome of the extremities, which is statistically more often detected in the lower extremities [17]. An analysis of clinical cases of combined gunshot wounds by Ertekin also emphasized the importance of urgent primary surgical procedures in the area of wounded limbs [18]. According to S. R. Sabapathy et al., wrong decisions and the choice of treatment tactics in the first hours after the injury of the patient lead to an increase in the risk of infection and secondary amputation [19]. Patients treated according to the old protocols are particularly at risk.

Second, the primary surgical treatment of wounds as soon as possible after injury (taking into account the medical and tactical situation and the technical capabilities of medical personnel) using microsurgical techniques, lymphatic drainage, and primary osteosynthesis is an effective tactic in the course of restoring damaged tissues (loose fibrous tissue, macrovascular and microcirculation, and muscle fibers) and structures (bones, fascia, and ligamentous apparatus). Lymphotropic administration of antibiotics with local lymphostimulation in the studied groups showed accelerated healing rates and stable and long-term drug concentrations in the regional lymph nodes compared with the control subgroup. An analogous tactic is also presented in the scientific work of M. Kumar et al. [20].

Scientists have performed surgical treatment with osteosynthesis in a hospital for the treatment of gunshot wounds of the upper limbs with fractures of the humerus. The treatment yielded positive results in these dynamics. The authors of this work focused on an integrated approach with the mandatory treatment of regional soft tissues and control of their remodelling and functioning. In a streaming study, the effectiveness of the TEPA scheme was demonstrated at the histological level. In the work of D. M. Clark et al., it is proposed to treat combined wounds using the technique of percutaneous covering [21]. This tactic of treatment contributes to the full overlap of different types of fractures without additional damage to the soft tissues with reliable fixation. According to the results of this study, clinical cases of multiple and combined gunshot wounds were effectively solved using this method, including the condition of the soft tissues. In a streaming study, disabled surgical interventions were also used in the form of autodermoplasty with a free flap, osteosynthesis, and plastic surgery with local tissues. The autodermoplasty method did not result in complications in the form of sepsis or suppuration in the studied groups.

Third, a full-fledged, timely course of lymphotropic antibacterial and decongestant therapy in the form of lymphostimulation is recommended for use in cases of complex and isolated gunshot wounds. This combination of therapeutic methods resulted in a faster and histologically adequate process of healing and recovery of wound damage in comparison with the control subgroup that received standard treatment without lymphotropic stimulation. The effectiveness of early antibiotic therapy is shown in the work of M. P. Nguyen et al. [22]. This study was conducted on more than 500 patients with gunshot wounds to compare single- and double-dose antibiotic therapy with first-generation cephalosporins. The incidence of infections requiring invasive treatment was almost 1.0%, while the total rate of complications in the form of sepsis, suppuration, or osteomyelitis was 11%. Infectious complication rates were not adjusted for age, injury location, multiple wounds, fractures, or type of surgical treatment used. The use of the proposed intensive antibiotic therapy protocol showed a statistically significant effect in reducing the development of infectious complications on the first day without the need for additional classes of antibiotics. In an ongoing study, the type of injury was not associated with the predictor probability of developing infectious complications. In the vast majority of cases, specialized care includes the primary treatment of wounds with primary or primary delayed sutures, extrafocal osteosynthesis, and autodermoplasty. The most common complication after invasive treatment was infectious inflammation in the form of wound suppuration, the treatment of which showed positive dynamics during lymphatic therapy.

An additional method for the treatment of multiple gunshot wounds, especially in the chest, was presented in Ya. Zarutskyi et al. used negative-pressure wound treatment [23]. The authors demonstrated the effectiveness of this method on real gunshot wounds, with a proven effect on the activation of the formation of granulation tissue, reducing dermotension, and the risk of suppuration. S. Emmert et al. also suggest the use of biocompatible cold plasma as an additional method for the treatment of gunshot wounds in the long-term and chronic periods in order to improve the circulatory and lymphatic microcirculation of soft tissues [24]. Treatment with cold plasma can be an addition to the long-term treatment complex used in ongoing studies, since plasma promotes active healing, stimulates fibroblasts and myofibroblasts, and initiates neovasculogenesis at the level of the microvasculature. According to L. C. Sharma and Jose reported that lymphotherapy in combination with microsurgical techniques is highly effective in complex combined gunshot wounds of the maxillofacial region [25]. This is especially true for injuries to the main neurovascular bundles, followed by ruptures of the walls of the blood and lymphatic vessels. At the tissue level, all three layers of the vessel walls are affected, which leads to the formation of thrombotic masses, extensive inflammation, spasm of smooth wall myocytes, and swelling. Treatment in such cases should include surgical treatment of the wounds, elimination of active bleeding, serial sanitation, and excision of necrotic masses.

The scientific work of Gonzalez et al. is devoted to the study of gunshot wounds of the lower extremities with bone fractures, which was also included in the ongoing study [26]. The authors identified six factors that determine the tactics of managing a patient with such a diagnosis: the kinetic energy of the projectile at the time of injury, the nature of the inlet, the calibre of the bullet, the depth of the gunshot lesion, the nature and condition of the regional soft tissues in the wound channel, and the type of damage to the limb (overstretching, rupture, squeezing). The flow study

also considered the nature of the wound path, condition of the regional tissues, and type of damage received. Considering the results of the study, Gonzalez et al. pointed to antibiotic therapy (III-IV generations of drugs) and surgical correction as the most effective treatment strategies during the first day after injury. The study conducted in this study also correlates with this position, but the use of lymphotherapy showed accelerated healing results compared with the group receiving the standard combination of treatment methods.

The data obtained from this study can be actively used in rehabilitation therapy programs. A study of patients in the process of rehabilitation after multiple and combined gunshot wounds of the extremities by N. Shestopal et al. showed that the use of an integrated approach to restore the physical and functional work of the limbs contributes to the psychological recovery of the victim from a position of independence and full vitality [27].

Conclusions

Considering the relevance of the problem of managing patients with isolated and combined gunshot wounds of the extremities, four groups of patients were studied in a total of 169 wounded patients who were delivered initially immediately after the injury or were redirected from other medical institutions. The experimental groups received lymphotropic therapy, which showed sufficient concentrations of applied antibiotics in the regional lymph nodes compared with the control group. The presence of the required concentration of the antibiotic regionally in the wound area for a long period resulted in low rates of diagnosing infectious complications on days 5-7 of treatment. In the control group, the drug was eliminated from the lymph nodes much faster, thereby slowing down the process of tissue clearance in the area of damage, especially in the presence of fractures. In the experimental group of patients who underwent regional lymphatic antibiotic therapy, a decrease in the volume of interstitial edema was observed on the fifth day after the injury.

Remodelling of damaged tissues (soft, bone, and muscle) in patients undergoing lymphotropic treatment was histologically observed on the seventh day, including the formation of new vessels and reduction of swelling and proliferation. In each group, surgical methods of treatment were also used in the form of primary surgical treatment of wounds, imposition of primary delayed sutures, autodermoplasty, primary extramedullary osteosynthesis, and extrafocal. Timely debridement with lymphotropic antibiotic therapy allowed suturing in 66% of the patients. Infectious complications were observed in only 2.5% of these patients. Future studies should include patients with visceral trauma to compare lymphatic drainage techniques in the presence of larger lesions. The data obtained can improve the tactics of managing patients with gunshot wounds both in the early and in the rehabilitation period of treatment to prevent infectious complications and soft tissue necrosis, as well as to improve the functionality of the injury zone.

Authors' contribution

Conceptualization, M.K.; methodology, M.K.; software, M.K.; validation, M.K.; formal analysis, M.K.; investigation, M.K.; resources, M.K.; data curation, M.K.; writing—original draft preparation, M.K.; writing—review and editing, M.K.; visualization, M.K.; supervision, M.K.; project administration, M.K.; funding acquisition, M.K. The author has read and agreed to the published version of the manuscript.

Funding source

This research received no external funding. The APC was funded by the author.

Ethics approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Andijan State Medical Institute (protocol code ASM-2025-12 and date of approval: 15 December 2025).

Consent for publication.

Informed consent was obtained from all subjects involved in the study. Written informed consent for publication was obtained from the patients for publication of the clinical and scientific data included in this article.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical restrictions related to patient information.

Acknowledgments

The author expresses sincere gratitude to the staff of the Department of Surgical Diseases and Civil Defense of Andijan State Medical Institute for their scientific and technical support during the study. Special thanks are extended to the medical personnel involved in the diagnosis, treatment, and follow-up of patients included in this research.

Conflict of interest

The author declares no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

MSCT	Multislice computed tomography
TEPA	Tissue edema prevention approach
IV	Intravenous
APC	Article processing charge
CT	Computed tomography
H E	Hematoxylin and eosin staining

References

[1] Baum, G.R., Baum, J.T., Hayward, D., MacKay, B.J. 2022. Gunshot wounds: Ballistics, pathology, and treatment recommendations, with a focus on retained bullets. Orthopedic Research and Reviews, 14, 293-317.

[2] Goel, R., Zhu, X., Makhani, S., Petersen, M.R., Josephson, C.D., Katz, L.M., Shaz, B.H., Austin, R., Crowe, E.P., Ness, P.M., Gehrie, E.A., Frank, S.M., Bloch, E.M., Tobian, A.A.R. 2021. Blood transfusions in gunshot-wound-related emergency department visits and hospitalizations in the United States. Transfusion, 61(8), 2277-2289.

[3] Wang, Y., Chen, Q., Dang, X., Lu, W., Zhang, X., Yan, H., Niu, S., Yan, X., Yan, J. 2023. A bibliometric analysis on traumatic brain injury in forensic medicine of a half-century (1972-2021). Frontiers in Neurology, 14, 913855.

[4] Circo, G.M., Wheeler, A.P. 2021. Trauma center drive time distances and fatal outcomes among gunshot wound victims. Applied Spatial Analysis and Policy, 14, 379-393.

[5] Zeineddin, A., Williams, M., Nonez, H., Nizam, W., Olufajo, O.A., Ortega, G., Haider, A., Cornwell, E.E. 2021. Gunshot injuries in American trauma centers: Analysis of the lethality of multiple gunshot wounds. The American Surgeon, 87(1), 39-44.

[6] Abduraxmanovich, A.A., Alisherovich, U.X., Kodirkul ogli, T.Zh. 2021. Intestinal injury at combined abdominal injury. Academicia Globe: Inderscience Research, 2(6), 196-202.

[7] Yahyoev, S.O., Khodzhimatov, G.M. 2022. Diagnostic methods and surgical treatment of patients with thoracoabdominal traumas (review of the literature). Polish Journal of Thoracic and Cardiovascular Surgery, 19(4), 226-231.

[8] Okhunov, A.O., Boboev, K.Kh. 2023. Etiological factors leading to purulent mediastinitis. World Bulletin of Public Health, 18, 118-125.

[9] Benjamin, E. R., Demetriades, D., Owattanapanich, N., Shackelford, S.A., Roedel, E., Polk, T., Biswas, S., Rasmussen, T. 2022. Therapeutic interventions and outcomes in civilian and military isolated gunshot wounds to the head: A department of defense trauma registry and ACS TQIP-matched study. Annals of Surgery, 10-1097. https://pubmed.ncbi.nlm.nih.gov/35786669/

[10] Jakobsen, L.S., Christensen, M.T., Lundemose, S.B., Munkholm, J., Bugge, A.B.D., Lynnerup, N., Banner, J. 2021. Life-threatening danger assessments of penetrating injuries in Eastern Danish clinical forensic medicine. International Journal of Legal Medicine, 135, 861-870.

[11] Luria, S. 2022. Treatment of upper extremity palsies, gunshot wounds and scaphoid nonunion: my preferred approaches. Journal of Hand Surgery (European Volume), 47(6), 580-589.

[12] Strafun, S.S., Kurinnyi, I.M., Borzykh, N.O., Tsymbaliuk, Y.V., Shypunov, V.G. 2021. Tactics of surgical treatment of wounded with gunshot injuries of the upper limb in modern conditions. Herald of Orthopaedics, Traumatology and Prosthetics, 2(109), 10-17.
[13] Khomenko, I.P., Lurin, I.A., Korol, S.O., Shapovalov, V.Y., Hrebennikov, K.O., Halushka, A.M., Tertyshnyi, S.V., Matviichuk, B.V. 2020. Organization of sorting and surgery of wounds with soft tissue defects during the joint force surgery. Journal of Education, Health and Sport, 10(1), 259-269.
[14] Omid, R., Stone, M.A., Zalavras, C.G., Marecek, G.S. 2019. Gunshot wounds to the upper extremity. JAAOS-Journal of the American Academy of Orthopaedic Surgeons, 27(7), 301-310.
[15] Meade, A., Hembd, A., Cho, M.-J., Zhang, A.Y. 2021. Surgical treatment of upper extremity gunshot injures: An updated review. Annals of Plastic Surgery, 86(3), 312-318.
[16] Hlavaty, L., Roquero, L., Amley, J., Root, K., Ishikawa, M., Koopmeiners, A., Zhao, L., Sung, L. 2019. Discordance of gross and histologic findings in estimating the range of fire of gunshot wounds. Journal of Forensic Sciences, 64(5), 1399-1411.
[17] Maddry, J.K., Mora, A.G., Perez, C.A., Reeves, L.K., Paciocco, J.A., Clemons, M.A., Sheean, A., Kester, N.M., Bebarta, V.S. 2022. Characterization of long-range aeromedical transport and its relationship to the development of traumatic extremity compartment syndrome: A 7-year, retrospective study. Military Medicine, 187(1-2), 224-231.
[18] Ertekin, A. 2021. Analysis of patients admitted to the emergency department with gunshot wounds. Journal of Surgery and Medicine, 5(5), 482-485.
[19] Sabapathy, S.R., Venkatramani, H., Mohan, M. 2019. Initial assessment, debridement, and decision making in the salvage of severely injured lower extremity. Indian Journal of Plastic Surgery, 52(1), 10-16.
[20] Kumar, M., Khatri, J.P., Singh, C.M. 2021. High Velocity Gunshot Fractures of Humerus: Results of Primary Plate Osteosynthesis. Indian Journal of Orthopaedics, 55, 714-722.
[21] Clark, D.M., Napora, J.K., Eglseder Jr, A. 2020. Percutaneous plate osteosynthesis of ulnar shaft fractures: a surgical technique and case series. Techniques in Hand Upper Extremity Surgery, 24(3), 119-125.
[22] Nguyen, M.P., Savakus, J.C., Simske, N.M., Reich, M.S., Furdock, R., Golob, J.F., McDonald, A.A., Como, J.J., Vallier, H.A. 2022. Single dose IV antibiotic for low-energy extremity gunshot wounds: a prospective protocol. Annals of Surgery Open, 3(1), e136.
[23] Zarutskyi, Ya., Aslanyan, S., Kravchenko, K., Vovk, M., Honcharuk, V. 2021. The use of negative pressure vacuum therapy in the treatment of soft tissue defects in thoracic injury. Norwegian Journal of Development of the International Science, 59, 17-23.
[24] Emmert, S., Bernhardt, T., Schäfer, M., Semmler, M.L., Bekeschus, S., Masur, K., Gerling, T., Wahl, Ph., Fischer, T., Boeckmann, L. 2022. Cold Plasma Treatment for Chronic Wounds. In: Textbook of Good Clinical Practice in Cold Plasma Therapy (pp. 141-160). Cham: Springer.
[25] Sharma, L.C., Jose, M.A. 2021. Gunshot injuries of the maxillofacial region. In: Oral and Maxillofacial Surgery for the Clinician (pp. 1267-1281). Singapore: Springer.
[26] Gonzalez, T., Briceno, J., Velasco, B., Kaiser, P., Stenquist, D., Miller, C., Kwon, J.Y. 2020. Gunshot-related injuries to the foot ankle. Foot Ankle International, 41(4), 486-496.
[27] Shestopal, N., Balazh, M., Kovelska, A., Kikh, A., Tomanek, M., Grygus, I. 2021. Effect of rehabilitation program on the quality of life of people with forearm or hand gunshot wounds using physiotherapy methods. Journal of Physical Education and Sport, 21(5), 2591-2600.