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Editorial Committee

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CONTENTS

Medical Bulletin of the Main Military Clinical Hospital named after N.N. Burdenko

Treatment of gunshot wounds of extremities using physical and orthobiological methods

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Abstract. Currently, despite the wide possibilities in the treatment of wounds, patients with gunshot wounds of the extremities present a complex surgical task.

The study included 60 patients with gunshot wounds of the extremities who underwent inpatient examination and treatment at the Center of Traumatology and Orthopedics of the Main Military Clinical Hospital named after academician N.N. Burdenko of Ministry of Defence of the Russian Federation. The patients were divided into groups. In group I, physical methods of treatment were used, such as vacuum therapy (35 people), of which 19 patients underwent combined vacuum therapy with laser irradiation of the wound (group IA), 16 patients underwent vacuum therapy in combination with high-intensity pulsed optical irradiation (group IB). Group II included patients in whom orthobiological techniques were used in the complex treatment of wounds (25 patients), including platelet-enriched fibrin glue — in 13 patients (group IIA) and a composition of heterogeneous implantable gel *Sphero*GEL® in the LONG version (hereinafter *Sphero*GEL®) — in 12 patients (group IIB).

Results. Comparison of the results of the treatment revealed a significant improvement in the regenerative process according to the histological method in group IA: the maturation of mature granulation tissue was observed on the 9th day after the application of local treatment methods. Positive adhesive and wound healing effects were observed in group IIA. According to the "AnalyRan" program, there was a significant reduction in the time of wound healing in all groups under study. According to the results of the study, all techniques showed positive dynamics of wound healing and reduction of the inflammatory process.

Keywords: wound, laser, ultraviolet irradiation, platelet-rich fibrin glue, *Sphero*GEL®.

Introduction. In case of gunshot wounds a morphological cascade of pathological changes occurs in soft tissues which were described in the works of N.I. Pirogov, H. Dupuytren, T. Billroth, E.T. Kocher et al. According to morphological and functional changes within the wound channel three zones of a gunshot wound are distinguished: wound defect, primary necrosis, secondary necrosis (the zone of "molecular concussion" according to N.I. Pirogov) [1]. Reconstructive-plastic surgical interventions are currently used to close wounds accompanied by soft tissue defect and to enable transition to sequential osteosynthesis; however, the period of wound preparation for plastic surgery in gunshot wounds is rather long and is determined by morphological changes in soft tissues. At the same time, there are a number of promising techniques of local intervention, which allow significant shortening of the healing time of a gunshot wound. Various methods of local treatment based on physical properties and methods of orthobiology are promising [2–6].

The article reviews clinical experience of using vacuum therapy in combination with laser or ultraviolet irradiation, autologous platelet-enriched fibrin glue and *Sphero*GEL® in the LONG version (further referred to as *Sphero*GEL®) in patients with gunshot wounds.

Materials and methods. The study included 60 patients with gunshot wounds of the extremities who had undergone inpatient examination and treatment in the Center of Traumatology andat the Center of Traumatology and Orthopedics of the Main Military Clinical Hospital named after academician N.N. Burdenko. All the victims were male servicemen. The mean age was 33.9 years (range, 20-49 years). The study groups were recruited consecutively. The patients were admitted for inpatient treatment on the average on the 1st-2nd day after the injury. All patients received traditional treatment which consisted in primary and recurrent surgical treatment of gunshot wounds of extremities using Pulsavac debridement systems, antiseptic solutions (chlorhexidine, betadine), antibacterial ointments, and medication therapy. All the wounded upon admission were examined for wound flora and sensitivity to antibacterial agents. To assess the severity of soft tissue injuries the Gustilo-Anderson classification was used (Table 1), which takes into account the amount of energy, degree of soft tissue damage, degree of contamination, and risk of complications.

The patients were divided into groups. Group I consisted of the wounded with Gustilo-Anderson type IIIB-IIIC soft tissue injuries, who were treated with such physical treatment as vacuum therapy (35 patients), of which 19 patients had vacuum therapy combined with low-intensity laser irradiation of the wound (Group IA), 16 patients had vacuum therapy combined with high-intensity pulsed optical irradiation (Group IB). Group II included patients with Gustilo-Anderson type II-IIIA soft tissue injuries in which orthobiological methods were used in the complex treatment of wounds in order to stimulate reparative regeneration (25 patients). In group IIA we used platelet-enriched fibrin glue (13 patients), in group IIB (12 patients) — *Sphero*GEL® (BIOMIR JSC, Russia) (Table 2).

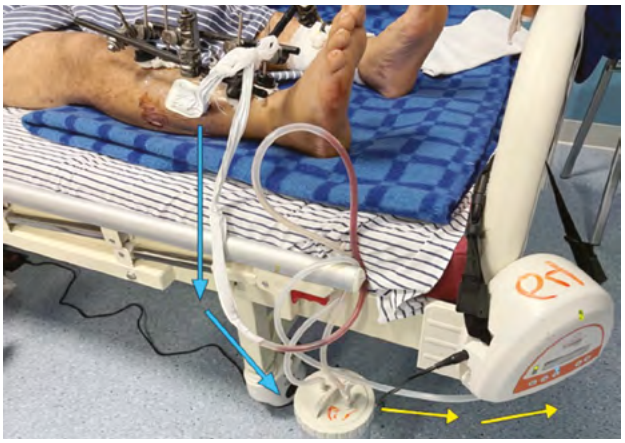
In 58.3% (35 patients) we performed vacuum therapy in the mode of constant vacuum aspiration or in the mode of vacuum-instillation therapy of the drug solution in the wound. From the first day of vacuum therapy a constant level of negative pressure (100-120 mm Hg) was established.

Table 1. Gustilo-Anderson classification

Type	Characteristics
Type I	A small wound (<1 cm) usually caused by a bone fragment penetrating the skin from the inside. By definition, such injuries do not include contaminated wounds. Bone damage is represented by a simple type of fracture: spiral or oblique short fracture
Type II	A large wound (1 to 10 cm) is observed. Contusion of soft tissue structures. More complex type of fracture
Type III	Extensive soft tissue injury, which may include: severe skin and subcutaneous tissue injury or necrosis; large single or multiple lacerations; muscle contusion or crushing; major vascular and/or nerve damage or gross contamination
Type IIIA	Wounds meet type III criteria, but do not usually require flaps or vascular repair for closure; no exposed bone from periosteum
Type IIIB	Lesions are accompanied by widespread soft tissue trauma or defect, usually highly contaminated. There is periosteum detachment and bone exposure requiring soft tissue closure
Type IIIC	Wounds are accompanied by vascular damage, which require restoration regardless of the degree of soft tissue damage

Table 2. Distribution of patients by group

Group I. Physical methods of treatment, n=35 (58,3%)		Group II .Orthobiology methods, n=25 (41,6%)	
IA vacuum therapy + low-intensity laser irradiation, n=19 (31,6%)	**IB** vacuum therapy + high-intensity pulsed optical irradiation, n=16 (25,7%)	**IIA** fibrin glue enriched with platelets, n=13 (22,7%)	**IIB** *Sphero*®GEL, n=12 (20%)



A

B

Fig. 1. Appearance of vacuum therapy devices: A — permanent vacuum aspiration mode; B — vacuum-instillation therapy mode; yellow arrow — vacuum phase (creation of negative pressure from the flask; blue arrow — vacuum phase (creation of negative pressure from the wound), green arrow — instillation phase (delivery of the drug solution into the wound)

A

B

Fig. 2. A — treatment of the wound with FiberLase CR; B — treatment of the wound with "Zarnitsa-A" apparatus

Vacuum-instillation mode included: vacuum mode — 2 minutes, instillation mode — 15-20 s, with solution volume of 20-25 ml, exposition mode — 1 minute, then the cycle was repeated for 60 minutes, the number of cycles per day — 3, with the average consumption of the drug solution — 1200 ml. The average period of sponge change was 72±24 hours. The course of treatment with vacuum therapy was 8–13 days (Fig. 1).

In some patients (16.6%), autologous platelet-enriched fibrin glue was used in order to close the soft tissue defect by autodermoplasty with a split perforated graft.

Vacuum therapy and low-intensity laser irradiation; vacuum therapy and high-intensity pulsed optical irradiation; autologous platelet-enriched fibrin glue; *Spheron*GEL® were used in surgical wound treatment.

In the operating room under anesthesia, low-intensity laser (Fig. 2A) or high-intensity pulsed optical

irradiation was performed on the wound (Fig. 2B). Laser irradiation was performed single time on FiberLase CR apparatus in the medium power mode of 3 W, exposure time — 7 minutes, pulse duration — 50 μs, using a tunable nozzle. High-intensity pulsed optical irradiation was performed on "Zarnitsa-A" apparatus, light flashes with a frequency of 5 Hz were conducted for 60 s (3 irradiation cycles).

After treating and delimitation of the surgical field, all patients underwent surgical treatment of the wounds (Fig. 3A). The first step, if necessary, was wound dissection (Fig. 3B); fasciotomy was performed to prevent compartment syndrome.

During the treatment all foreign bodies, fragments, and fragments of the uniform were removed (Fig. 4A). Wound lavage was performed using Pulsavac debridement systems, with chlorhexidine and betadine solutions (Fig. 4B).

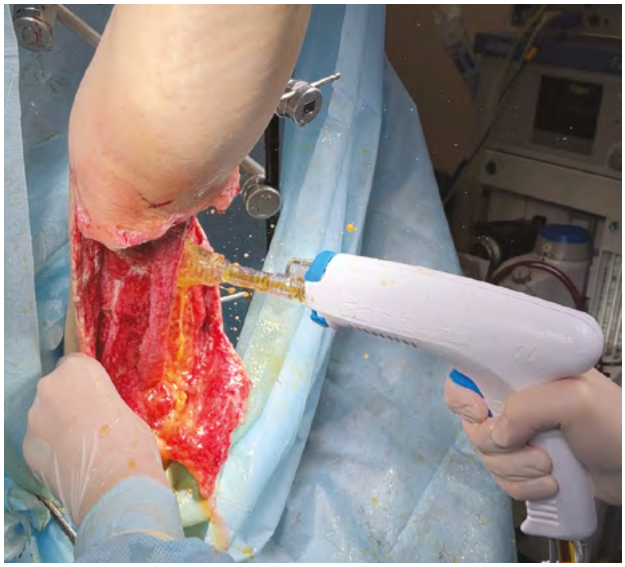
An important step is the excision of non-viable tissue, depending on the nature of the wound (Fig. 3B). Muscle viability was assessed using the four "C" rules: color, consistency, capacity to bleed, and contractility. Wound drainage was performed both passively with wide single-lumen half-tubes as well as using vacuum drainage and VAC (vacuum-assisted closure) systems (Fig. 1) in order to create the outflow of wound effluent.

A

B

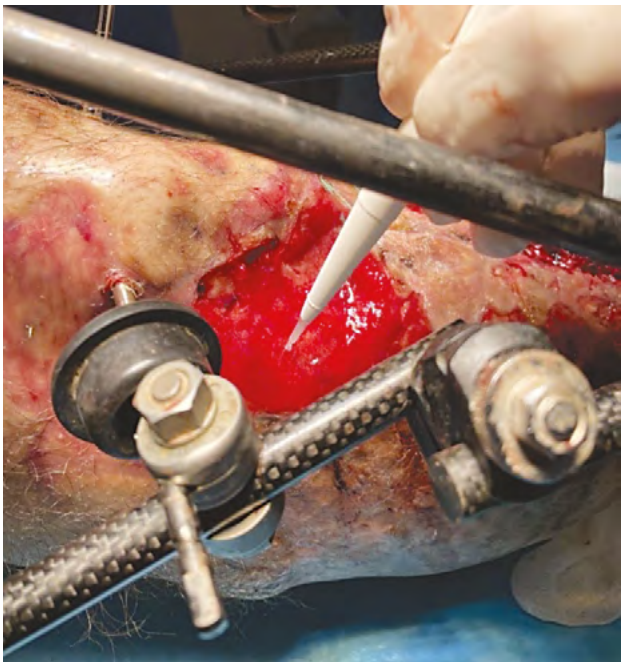
Fig. 3. A — surgical treatment of the thigh wound; B — wound dissection with excision of nonviable tissues performed with the possibility of further replacement of local tissues by the counter-flap method

A

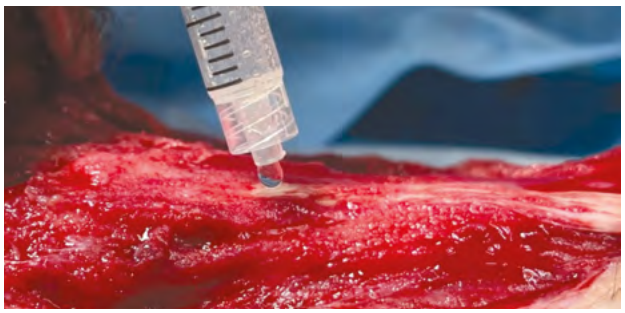


B

Fig. 4. A — removed foreign bodies; B — surgical treatment with the Pulsavac debridement system

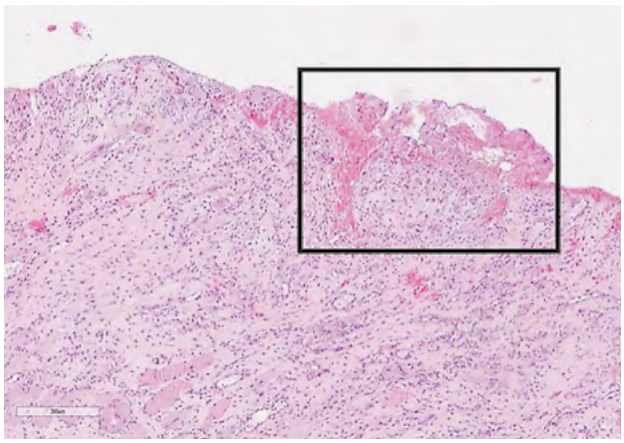


A

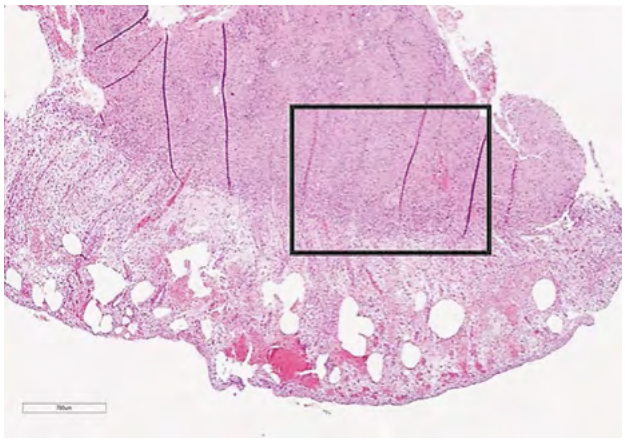


B

Fig. 5. A — application of autologous platelet-enriched fibrin glue; B — intraoperative injection of *Sphero*GEL®



A



B

Fig. 6. Histological picture after gunshot wound on the 1st (A) and 10th (B) day after vacuum therapy and laser irradiation

Patients with soft tissue defects which did not require complex reconstructive and plastic surgery underwent intraoperative application of autologous platelet-enriched fibrin glue obtained using the Vivostat system or *Sphero*GEL® directly on the wound defect (Fig. 5).

Postoperative period. In the postoperative period all patients received antibacterial, anticoagulant, analgesic drug therapy. Additional physiotherapeutic treatment was not used in order to analyze the results objectively. Each patient received individual sessions and recommendations with the participation of physical therapy instructors.

Methods of treatment evaluation. To assess the dynamics of the wound process we used histological method, "AnaliRan" digital image analysis program, bacteriological examination, laboratory diagnostic methods. Histological verification was performed as an objective method of the phase of reparative process in the wound. It enabled to estimate the peculiarities of the wound process course and determine the readiness of the wound for the reconstructive-plastic surgical treatment. By using "AnaliRan" pro-

Table 3. Distribution of wound process phases according to histological examination on the 5th day after wounding

Groups	Histological picture
IA Vacuum therapy + laser irradiation	Regeneration phase. Mature granulation tissue predominates
IB Vacuum therapy + high-intensity broadband pulsed optical irradiation (xenon lamp)	Regeneration phase. Immature granulation tissue
IIA Fibrin glue enriched with platelets	The phase of exudation, turning into regeneration. Reduction of inflammation and formation of granulation tissue
IIB *Sphero*®GEL	The phase of exudation turning into regeneration. Reduction of inflammation and formation of granulation tissue areas are noted

gram the dynamics of the wound healing was determined according to the parameters: wound area, epithelium, granulation, fibrin, necrosis, extension of borders. Bacteriological examination was performed in all the wounded to reveal the microflora, determine the sensitivity to antibacterial medication and the necessity of prescribing etiotropic antibacterial therapy (EAT). Laboratory blood and urine tests were performed to assess the inflammatory process and to monitor the general state of the body.

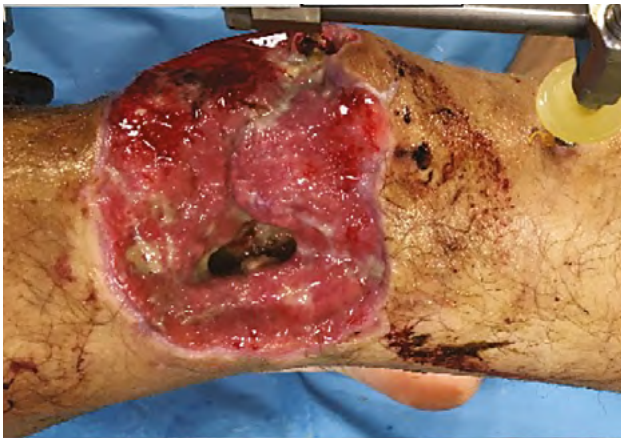
Results and discussion. Out of 60 patients, 85% (51 patients) it was able to monitor and obtain diagnostic data of the reparative process.

Comparing the results of the surgical intervention we noted a significant improvement of the reparative process according to histological data in group IA with the use of vacuum therapy and laser irradiation. On the 1st day, the exudation phase with the presence of fibrin and leukocytes was determined. On the 5th day mature granulation tissue was observed (Fig. 6).

Material was sampled for histological examination on the 1st, 4th, 8th and 12th days. Interpretation of the results was performed in the pathological anatomy department of the Main Military Clinical Hospital named after academician N.N. Burdenko with assessment of the morphological picture and determination of the phase of the wound process (Table 3).

In patients in group IIA (patients with II-IIIA types of injuries according to Gustilo-Anderson classification, for treatment of which autologous platelet-enriched fibrin glue was used) a positive adhesive and wound healing effect was observed, but it is important to follow the technique of the procedure to avoid formation of a dense film on the wound surface, which hinders the wound healing process.

According to the data of the digital analysis program "AniliRan", positive dynamics of the reparative process was observed in all groups of patients at different terms of wound healing in gunshot wounds of extremities (Fig. 7).



A

B

Fig. 7. Analysis of the dynamics of the wound process using the digital analysis program "AnaliRan": A — wound view before color correction, B — after color correction

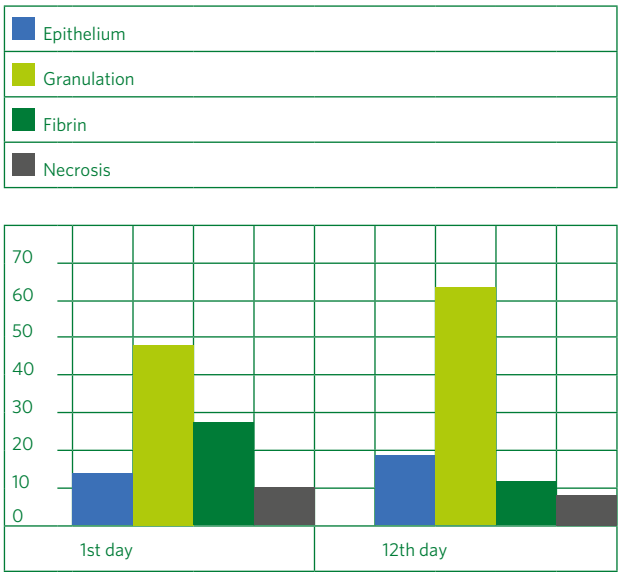


Fig. 8. Diagram of dynamics and wound healing in group IA

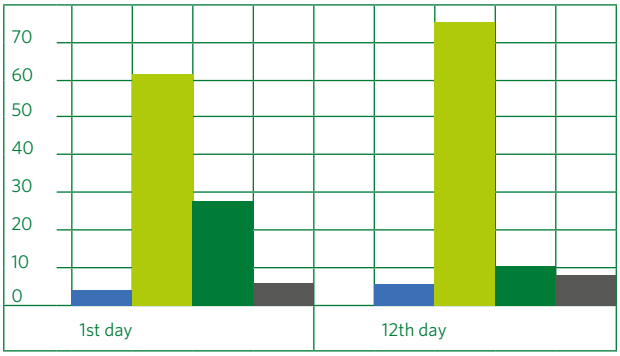


Fig. 9. Diagram of the dynamics of wound healing in group IB

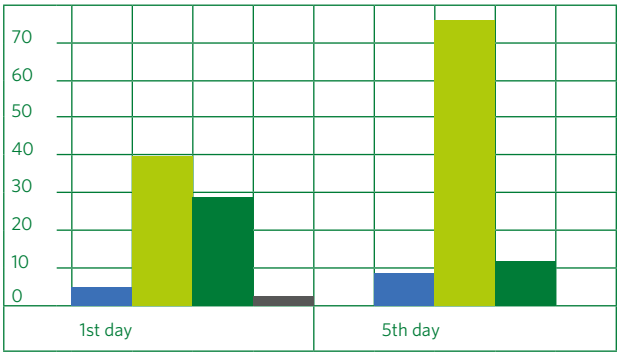
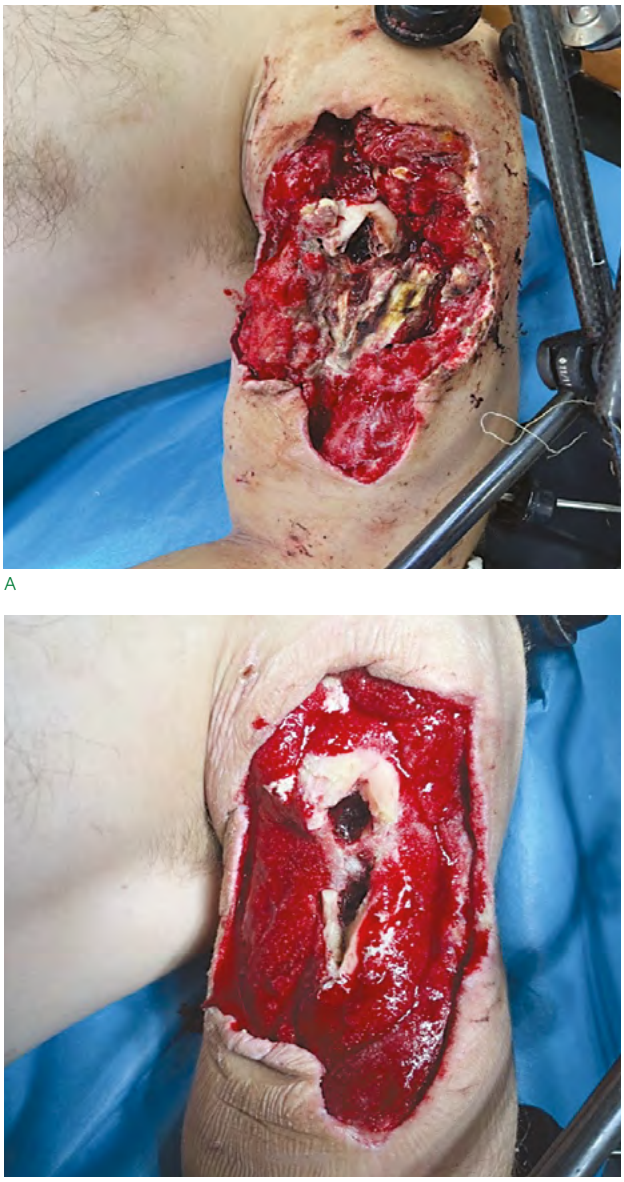


Fig. 10. Diagram of wound healing dynamics in group II



A

B

Fig. 11. Appearance of the wound on day 1 (A) from admission and day 10 (B) of treatment at the Trauma and Orthopedics Center

In group IA, the wound area decreased on average from 11538.91±1764.34 mm2 to 9345.32±567.12 mm2 on the 12th day. Boundary extension decreased from an average of 632.23±143.34 mm to 514.32±128 mm (Fig. 8).

In group IB, the wound area decreased from an average of 4925.67±345.56 mm² to 4565.92±365.54 mm² on the 12th day. Boundary extension decreased from an average of 330.29±56.76 mm to 310.78±43.56 mm (Fig. 9).

In group I patients (patients with IIIB-IIIC types of injury according to Gustilo-Anderson classification, to whom vacuum therapy combined with laser irradiation or high-intensity pulsed optical irradiation were applied) replacement of extensive soft tissue defects was performed

Table 4. Identification of microorganisms using a bacteriological analyzer

Type of the pathogen	The frequency of occurrence in the wound, %
Acinetobacter baumannii	12
Staphylococcus epidermidis	28
Klebsiella pneumoniae	24
Pseudomonas aeruginosa	3
Bacillus spp.	5
Enterococcus faecalis	26
Enterobacter cloacae ssp.	2

A

B

Fig. 12. Appearance of the wound on day 1(A) from admission and day 15 (B) of treatment at the Trauma and Orthopedics Center

Fig. 13. Reconstructive-plastic soft tissue defect replacement with a thoracodorsal flap

on the 3rd-4th week after the injury. The duration of the wound preparation period for reconstructive-plastic surgery was 23±2 days.

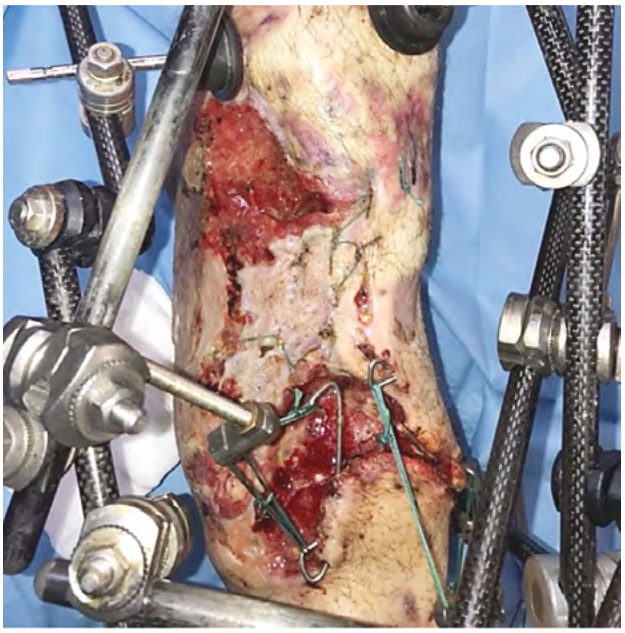
Both groups (IIA and IIB) showed positive dynamics of the reparative process in limb gunshot wounds (Fig. 10).

Bacteriological analysis revealed that Staphylococcus epidermidis, Klebsiella pneumoniae, Enterococcus faecalis were the most common. Determination of the pathogen type and its sensitivity to antibiotics allowed us to prescribe etiotropic effective antibiotic therapy, which also had a positive effect on the results of wound healing.

Clinical case 1. Patient A., born in 1987, was admitted with a gunshot fragmentation wound of the left shoulder with a comminuted fracture of the left humerus with displacement of bone fragments and soft tissue defect, type IIIB according to the Gustilo-Anderson classification. The external fixation apparatus (EFA) of the military-type rod kit (MTRK) and staged surgical treatments with the use of vacuum therapy and laser irradiation were performed (Fig. 11).

Clinical case 2. Patient N., born in 1992, was admitted with a gunshot fragment wound of the left forearm with a comminuted fracture of both forearm bones in the middle third with displacement of bone fragments and bone as well as soft tissue defects, type IIIB according to the Gustilo-Anderson classification. The EFA of the MTRK was applied and staged surgical treatments with the use of vacuum therapy and high-intensity pulsed optical irradiation were performed (Fig. 12).

On the 23rd day we performed reconstructive and plastic replacement of the soft tissue defect with a non-free thoracodorsal flap (Fig. 13).



A

B

Fig. 14. Complex treatment with platelet-enriched autologous fibrin glue: A — Wound appearance with dermotension; B — Wound appearance 6 weeks after application of platelet-enriched autologous fibrin glue

With soft tissue defects of types IIIB and IIIC according to the Gustilo-Anderson classification, it is preferable to use methods of local exposure in the form of vacuum therapy together with low-intensity laser or ultraviolet irradiation at the first stage in the absence of contraindications for these techniques. In type II-IIIA, autologous platelet-enriched fibrin glue or *Spheros*GEL® can be used both independently and in addition to skin plasty with local tissues or autodermoplasty with a perforated graft

Clinical case 3. Patient X., born in 1985, was admitted with a gunshot wound of the right shin with a comminuted fracture of both shin bones in the upper and lower thirds with displacement of bone fragments and bone and soft tissue defects, type IIIC according to the Gustilo-Anderson classification. The EFA of the MTRK was applied and staged surgical treatments with the use of vacuum therapy were performed. On the 20th day the soft tissue defect was plated with a nonfree musculocutaneous flap. On the 6th day after transplantation, partial necrosis of the flap and suppuration of the wound were observed. An attempt was made to close the soft tissue defect by dermotension. Multistage surgical treatments allowed to stop the inflammatory process, but there was a partial detachment of the flap, multiple soft tissue erosions, no wound healing dynamics in the upper third of the shin.

In order to close the soft tissue defect a split skin graft plasty with the use of autologous platelet-enriched fibrin glue was performed (Fig. 14). The results of 6 weeks after application were full engraftment of the transplant, closure of the soft tissue defect, and healing of the wound.

The patient was transferred to the subsequent reconstructive stage to restore the length and support ability of the injured limb.

Results and discussion. New data on the complex treatment of injuries in gunshot wounds obtained in a clinical study using different methods of regional impact extended the ideas about the reasonability of their clinical application in the military medical organizations. Application of vacuum therapy in combination with ultraviolet or laser irradiation as well as orthobiological products significantly reduces wound healing time and gives an opportunity to perform earlier reconstructive-plastic operations for soft tissue defect replacement.

Proper choice of the method of local exposure depending on the severity of the wound, the phase of the wound process, the size of the defect allows to reduce the period of treatment of the wounded and contributes to the early return to service.

Conclusion. During the study, all techniques showed positive dynamics of wound healing and reduction of the inflammatory process. According to the histological method, the development of mature granulation tissue on the 9th day after the use of low-intensity laser irradiation was observed. With soft tissue defects of types IIIB and IIIC according to the Gustilo-Anderson classification, it is preferable to use methods of local exposure in the form of vacuum therapy together with low-intensity laser or ultraviolet irradiation at the first stage in the absence of contraindications for these techniques. In type II-IIIA, autologous platelet-enriched fibrin glue or *Sphero*GEL® can be used both independently and in addition to skin plasty with local tissues or autodermoplasty with a perforated graft. At the same time, further studies and comparison of both short-term and long-term results of treatment in patients with gunshot wounds of the extremities are required.

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Surgical tactics in cases with large wounds of soft tissue of limbs and pelvis

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Abstract. In modern armed conflicts the incidence of multiple and combined limb wounds with extensive wound defects of the limbs and pelvis remains high and tends to increase [1].
Such wounds are accompanied by prolonged treatment period, high frequency of wound infection development (up to 35–80%), impossibility of early internal osteosynthesis and early rehabilitation, and rather high incidence of disability [2–4]. The closure of extensive defects in combination with the wound management algorithm in the early posttraumatic period reduces blood and plasma loss, the development of endotoxicosis and wound infection, significantly improves the results and outcomes of treatment, increasing the efficiency of wound healing and reducing the duration of patient treatment.

Keywords: battlefield medicine, trauma surgery, large wounds, wound infection, damage control.

Introduction. Injuries and traumas of the lower extremities and pelvis in peacetime make up 11–37% and 9–12% in the total structure of injuries. Severe traumas of the extremities are accompanied by extensive soft tissue injuries in 25–30% of cases, of the pelvis — in 0.5–1.5%. In wartime damages of extremities, according to recent local wars and armed conflicts, make up 47–61%, including extensive damages — 21.3%, pelvic injuries — 2.0–4.8%, including extensive damage — 10%. Such injuries are accompanied, among others, by extensive defects of muscle masses and skin lesions, which require their subsequent recovery, since it leads to blood and plasma loss, development of endotoxemia, wound infection, prevents the performance of early internal osteosynthesis in bone injuries and early rehabilitation [5]. Therefore, the closure of extensive soft tissue defects is one of the important treatment tasks.

Objective. To analyze the treatment of the injured and wounded patients with extensive soft tissue defects and to determine the optimal treatment tactics.

Material and Methods. The most common cause of extensive soft-tissue injuries of the limbs and pelvis is mine blast wounds and open mechanical trauma (rail, work, traffic accidents).

The notion of "extent of injury" is often found in Russian and foreign literature, but each author puts his own meaning into this term, so there is no unity in terminology and understanding of this problem.

The concept of extensiveness of injuries is present in different classifications, which are listed below.

Table 1. Characteristics of the array of wounded and injured

Criteria for the distribution of the injured and wounded under study	Characteristics of observations			
	1st group (n=56)		2nd group (n=120)	
	abs.	%	abs.	%
By age				
18–59 years old	48	86	114	95
Over 59 years old	8	14	6	5
By localization of extensive injuries				
upper extremities	8	14	31	25,8
thighs	7	13	25	20,8
shin	17	31	44	36,6
pelvis	3	5	13	10,8
trunk	3	5	7	5,8
including limb segment bone injuries	24	43	84	70
Tears/destructions of the extremities at the level of				
femur	3	5	13	10,8
shin	4	7	15	12,5
shoulder	7	13	7	5,8
forearm	4	7	9	7,5
By severity of injury (BM-I (Injuri))				
1,0–12,0 points (severe)	37	66	56	46,6
>12, points (extremely severe)	19	34	64	53,3

Fig. 1. Patient with an extensive defect of the right lower extremity as a result of a severe combined fragmentation wound

Classifications of extensive injuries [6–10]:

1. Limbs:
   - Gustilo-Anderson (grade III, wound more than 5 cm with extensive soft tissue damage (A, B, C);
   - Kaplan-Markova (IIB, IIIB, IV);
   - tear, partial tear, destruction (Battlefield medicine (BM);
   - Tscherne classification (III grade — major soft tissue injury with major vessel and/or nerve damage; IV grade — complete or incomplete amputation);
   - skin detachment classification (extensive over 200 cm^2 and limited to less than 200 cm^2);
   - Muller AO classification (1987).
2. Wounds of large joints of the 3rd group (with extensive soft tissue defect and considerable bone damage).
3. Wounds of the hand and foot — Usoltzeva classification (limited, extensive, destruction).

There are no classifications of the extent of pelvic, trunk, and head injuries due to the rarity of treating this type of injury at the hospital stage — typically, these injuries are incompatible with life.

Considering the lack of uniform terminology, we developed inclusion criteria: damage/defect of soft tissues of the skin, subcutaneous tissue, and underlying tissues over an area equal to or greater than 1/3 of a limb segment, pelvis, major joint, or detachment of a limb segment above the wrist and foot (Fig. 1). In most cases, these injuries required long-term multistage treatment and the use of techniques of plastic replacement of the defects of the covering tissues.

The experience in the treatment of extensive soft tissue injuries in 176 injured and wounded patients over the last 15 years was analyzed in the Clinic of Military Field Surgery. Group 1 included 56 (31.8%) injured and wounded patients who were initially admitted to the clinic. Group 2 included 120 (68.1%) patients transferred from other hospitals. The characteristics of the wounded and injured patients' groups are shown in Table 1. We did not

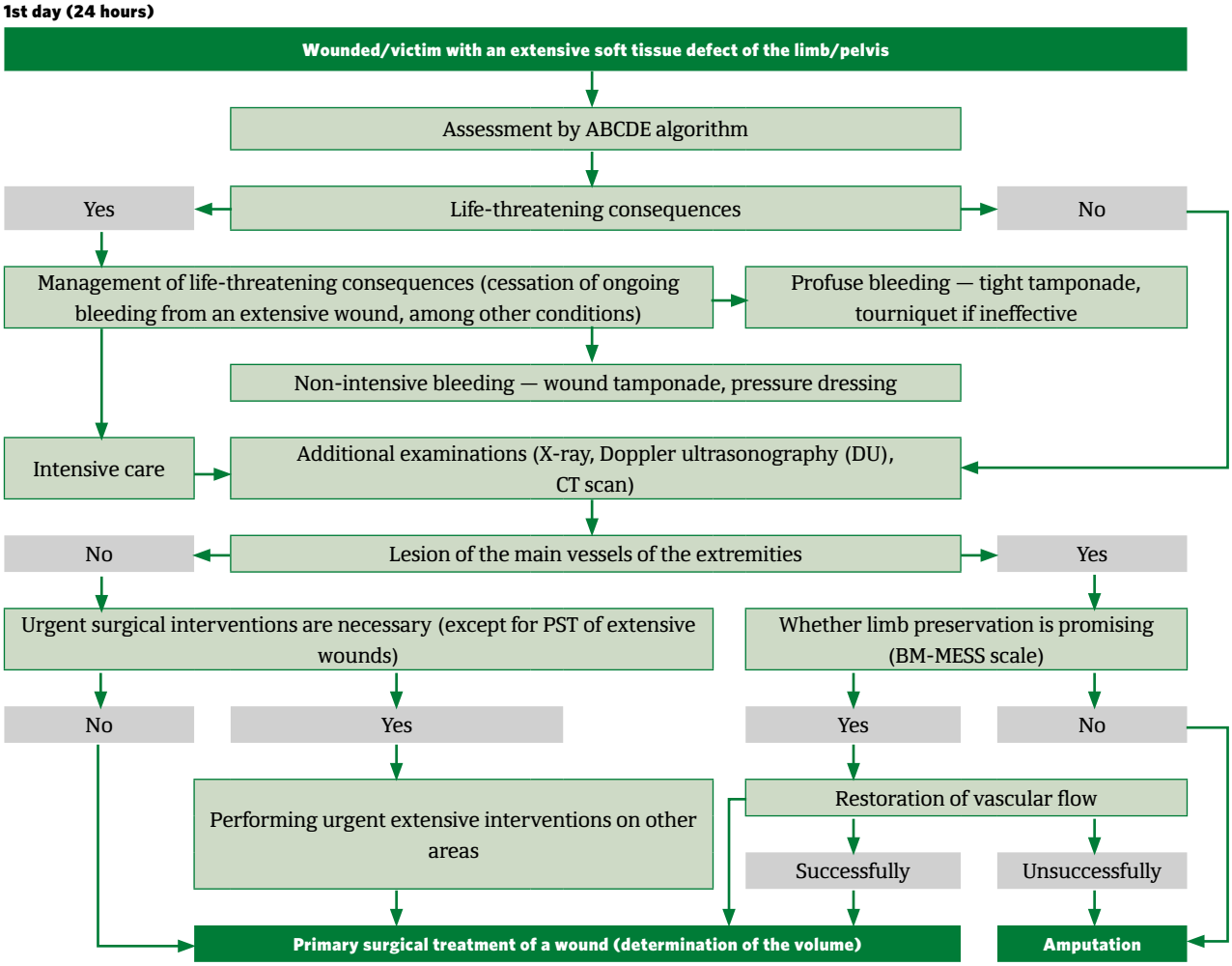

Fig. 2. Algorithm of examination of patients with extensive defects in pelvic and limb injuries on initial admission to the hospital

include patients with extensive burns and frostbites, since the algorithms of therapeutic tactics for this pathology have their own specific features and have already been developed.

Results and discussion. Treatment of the injured and wounded patients both at the initial admission and at the transfer from other medical institutions started with the examination and identification of the volume of injuries not only in the area of an extensive wound, but also in other areas. The examination of the patient upon admission was performed according to the ABCDE algorithm. The morphology of injuries of all localizations and the condition of the injured person were determined. Special attention was paid to the identification and rapid elimination of life-threatening consequences [11].

The surgical tactics at the initial admission of the patients (group 1) is shown in Fig. 2. On admission, temporary cessation of external bleeding from an extensive wound was performed in the quickest and simplest method. Primary surgical treatment (PST) of the extensive wound was performed after the patient's condition had stabilized and emergency and urgent surgical interventions on other areas had been performed. The scope of surgical intervention depended on the condition of the patient.

In the case of an unstable patient (Fig. 3), a multistage surgical tactics was decided upon. The first stage included cessation of bleeding, fasciotomy, application of aseptic dressing after wound debridement and abundant wound irrigation (physiological solution, bottled water). Bone fractures were treated with external fixation devices (rod type "combined trauma kit" — CTK, "military-type rod kit" — MTRK). In other cases, immobilization was achieved either with splints or in bed. At the second stage intensive therapy was carried out, aimed at compensating the vital functions of organs and systems. Subsequently, delayed/

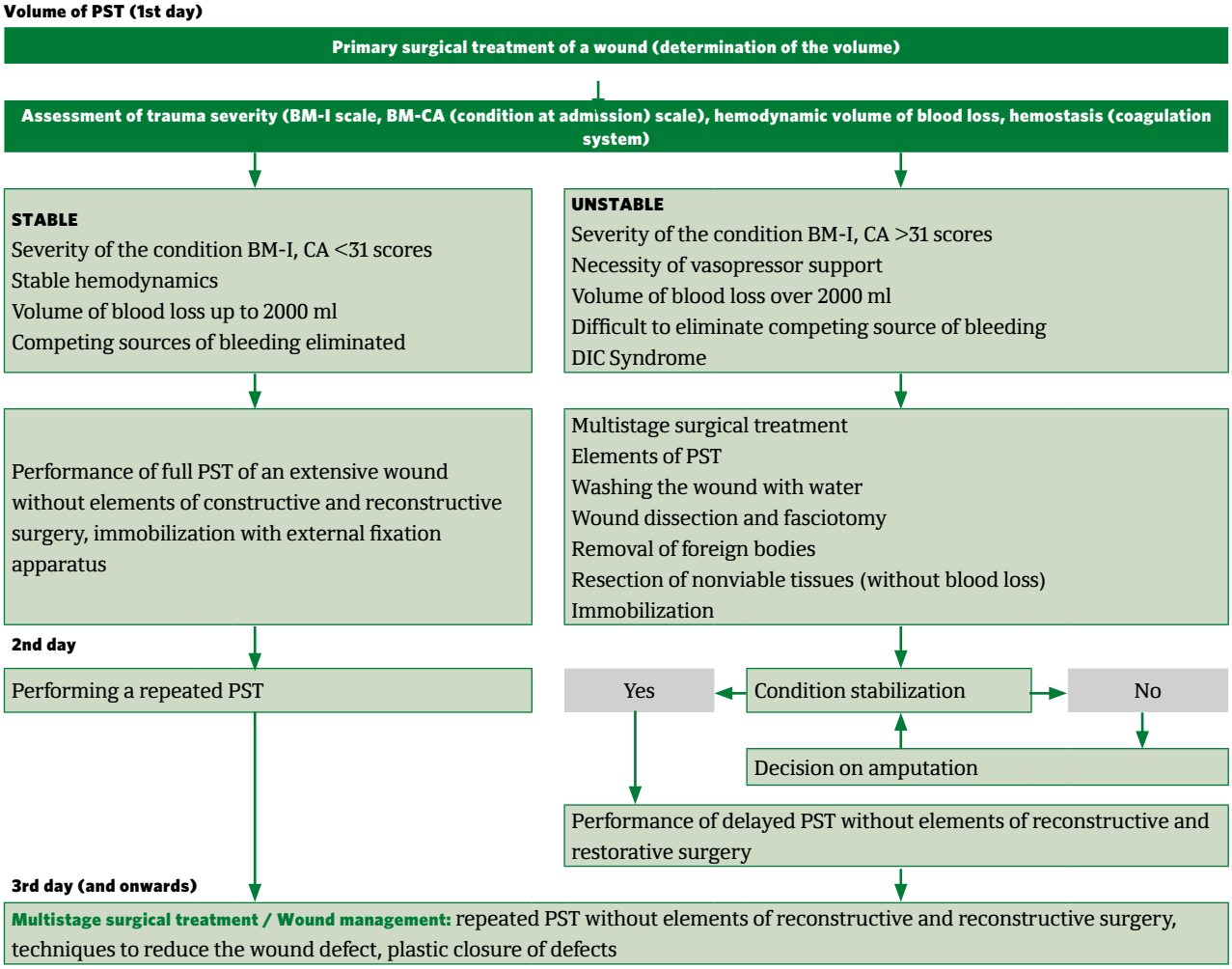

Fig. 3. Algorithm of treatment of patients with extensive defects in pelvic and limb injuries and determination of further tactics

repeated primary surgical treatment was performed on the 2nd day.

Immobilization of a limb segment with external fixation devices was mandatory after primary surgical treatment, even if there was no damage to the bones and ligamentous and joint apparatus. As a rule, a spoke-rod apparatus with "suspension" of the limb segment was used. At the end of the primary surgical treatment, the wound was not sutured tightly, even if the tissues allowed to bring the wound edges together without tension. Intradermal ligatures were applied to the skin edges and tied to the elements of the spoke-rod apparatus with moderate tension. The aim of the ligatures in the first 5 days was not dermatotension itself, but reduction of skin edge retraction and wound defect reduction in the conditions of increasing traumatic edema of peri-wound tissues [12–16]. As the traumatic edema decreased and the wound became cleaner, dermatotension was started (Fig. 3).

In 47 cases of Group 1 patients, a dressing with controlled negative pressure was applied to speed up wound clearing and reduce posttraumatic edema. Dermatotension was also used in these cases, with ligatures from different edges fixed to each other over the foam. Period of dermatotension was from 7 to 15 days and depended on the size of the wound defect, development of infectious complications, variant and type of the traumatic disease course. If dermatotension could not be continued and the soft tissue defect was preserved in 118 (63.4%) cases, final closure of the defects was carried out by moving non-free skin and muscle flaps or a free autograft.

In 10 patients of the 1st group, the wound was sutured with the primary-delayed suture on the 3rd–4th day if their condition stabilized and there were no signs of the wound infection. The wounds were abundantly washed with antiseptic solutions and adequately drained. In 100% of cases the wounds did not heal. On the 3rd-5th day from the moment of suturing, peri-wound phlegmon

A

B

Fig. 4. Dermatotension: A — stump closure in a patient with an amputated limb; B — closure of an extensive defect in a wounded patient as part of a multistage surgical treatment tactics

developed, the sutures were removed and secondary surgical treatment was performed.

Group 2 injured and wounded patients arrived in the third period of traumatic disease with life-threatening consequences of trauma eliminated and surgical treatments and transport immobilization performed in differing amounts.

In Group 2, 105 (87.5%) patients were transferred from other medical institutions in 3–10 days after injury; 72 of them had signs of wound infection in the form of periwound phlegmon of different extent, and 9 wounded patients had sepsis. The rest 15 injured and wounded patients were admitted later — on the 15th–30th days with the signs of subacute stage of the wound infection. At the admission of transferred patients there was a mandatory assessment of the inflammatory process, collection of material for bacteriological examination and examination according to systems similar to those of the initially admitted patients. This examination algorithm was mandatory due to the high incidence of undiagnosed injuries in the patients admitted from other medical institutions, as well as for detecting remote foci of an infectious process [17]. Then on the first day under general anesthesia a wound revision with repeated primary or secondary surgical treatment was performed in the operating room. In the third period of traumatic disease in the wounded and injured with extensive soft tissue injuries, a comprehensive approach was used in the treatment using the wound process management algorithm. This algorithm was aimed at clearing the wound of necrotic tissues, ensuring the outflow of wound discharge, suppression of wound infection agents, restoration of tissue viability surrounding the necrosis area by eliminating edema, recovery of microcirculation, normalization of biochemical processes.

The wound management algorithm was based on staged surgical treatments (primary or secondary) every 2–3 days until the wound was cleared and prepared for closure. We rejected primary and primary-retained sutures for extensive soft tissue injuries with wound management open until the wound was completely cleansed and the general condition of the patient was stabilized. In the course of surgeries, we used modern methods of physical impact on the wound: ultrasound cavitation and dressings with controlled negative pressure [18–23]. Immobilization of the limb segment and adjacent joints with external fixation devices was obligatory in case of extensive soft tissue injuries. In this case, preference was given to rod apparatuses that did not impede subsequent full access to the wound. Reduction of the wound area was achieved by dermatotension as described above. Then extensive defect closure was performed in the patients with no signs of systemic inflammation, organ dysfunction (SOFA=0 scores), the beginning of anabolic phase of the wound process (tendency to increase total protein level in the absence of albumin transfusion, appearance of signs of reparative processes on the wound side — reduction of edema and appearance of granulation tissue).

Plastic closure of the defects of the covering tissues should be carried out using the simplest and most reliable methods of plasty: with the application of secondary late sutures, transferred dermal or muscular flaps, free dermal plasty. Suppression of microflora in the wound was achieved by adequate and targeted antibacterial therapy taking into account microbiological control.

Both in the 1st and 2nd groups of the patients it took from 5 to 20 surgical interventions to close the wound. Wound healing time depended on the extent of injuries, intensity and duration of the infection process: in 64 (36%) patients — 15–20 days without wound infection, in 83 (47%) — 20–35 days, in 29 (16%) — over 35 days with the development of wound infection.

The analysis of the material also revealed the most frequent mistakes:

- early rigid immobilization with external fixation devices (even in the presence of fractures) was not performed in 44 transferred victims, which created poor conditions for wound healing (traumatization with bone fragments) and also contributed to the development of osteomyelitis;
- PST was either not performed or was not performed in full (in 79 victims);
- fasciotomies were not performed in 23 cases, leading to compartment syndrome and increased necrosis of muscle masses;
- early wound closure (in 16 wounded patients).

Conclusion. Thus, the treatment of the injured and wounded patients with extensive injuries should be carried out at the stage of specialized surgical care (in one medical institution, preferably by one specialist), as they require the use of considerable amount of material and human resources, which are limited at the frontline stages of medical evacuation.

Treatment of extensive wounds in the patients requires a differentiated approach to surgical tactics — assessment of condition and injury severity, multistage surgical tactics (damage control tactics) as the main method of treatment of extensive wounds in the injured and wounded with severe trauma.

Application of the algorithm for the treatment of the injured and wounded with extensive soft tissue injuries made it possible to control the wound process, prevent and eliminate the development of severe infectious complications as well as to improve the results of treatment of the patients with this pathology with subsequent rehabilitation and reconstructive treatment.

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Organization of eye care in modern armed conflicts: state and prospects

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Abstract. The main feature of modern armed conflicts is the use of new weapons and, as a result, changes in the nature and structure of eye injuries. This feature, on the one hand, and the rapid progress of medical science, on the other hand, require a rapid response to the changing operational situation using the resources of modern ophthalmology in order to provide care to wounded and injured ophthalmic patients efficiently and rationally.
There are some differences in approaches to pre-hospital self- and mutual aid to the wounded with ophtalmic injuries on the battlefield in different schools of military medical training and tactical medicine. Some use a binocular bandage, while others use a rigid eye shield.
The complexity and variety of visual injuries require good practical skills and experience in order to perform high-quality surgical treatment of perforated corneal and scleral wounds in open eye trauma. This necessitates a thorough training of specialists with practical skills.
The issue of medical supply of units providing specialized care at the stages of medical evacuation, which includes a military ophthalmologist, is particularly significant. The problem of reasonable and rational update of the ophthalmological equipment at the stages of medical evacuation requires active discussion.
There is still the question of the use of effective protective equipment for the eye during combat operations, which, without limiting visual function, could prevent combat eye injuries, most often caused by small fragments and secondary wounding projectiles.

Keywords: combat eye injury, ophthalmic care, military ophthalmology, open globe injury.

Relevance. The frequency of combat eye trauma is increasing, reaching 13% of all sanitary losses in the armed conflicts of the last decades [1]. During the Great Patriotic War, it was 1–2 % [2, 3], during armed conflict in Afghanistan (1979–1989) — 4.5 % [4], during antiterrorist operation in the North Caucasus (1999–2002) — 8 % [5–7].

From the works devoted to the Vietnam war (1955–1975) it is known that about 9% of all the wounded suffered eye injuries, at that only 25% of the injured ophthalmologists could return to the military service while among all surviving wounded the figure was 83% [1, 8].

Thus, the issue of improving the organization of care for the wounded of ophthalmic profile in the course

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Fig. 1. Severe binocular damage caused by secondary wounding projectiles of organic nature

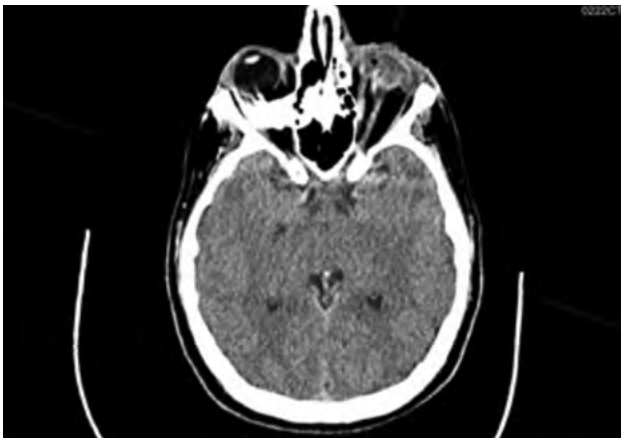

Fig. 2. Computed tomography of the head, axial projection. The left eyeball is sharply deformed, the fibrous capsule and lens are not clearly differentiated, and the contents are heterogeneous. Given the clinical picture, CT-signs of eyeball destruction

of medical support of modern armed conflicts is relevant.

The peculiarities of modern warfare and their influence on the structure of medical losses and the medical support of the troops. Modern armed conflicts are characterized by a change in the nature of warfare in the direction of increasing the maneuverability of the troops [9]. In this connection the forces and means of the medical service must also be able to move the stage of medical evacuation quickly depending on the operational situation [10].

When using new types of weapons, a large number of primary (metal fragments) and secondary (blast products, fragments of soil, plants) wounding projectiles with high kinetic energy are formed as a result of a powerful explosion, so the characteristics of the wounds received also change. They become more often combined, multiple and combined, the frequency of infectious complications increases [6, 11, 12].

The peculiarities of the military operations also change the character of injuries of the visual organ. There is an increase in the frequency of binocular lesions, severe consequences of multiple wounds to the eye with small secondary wounding projectiles, which lead to the development of infectious complications in a short time after the injury [5, 12, 13] (Fig. 1). On the other hand, the incidence of severe wounds to the maxillofacial region and skull, in which the wounding projectile leads to the destruction of the eyeball, remains fairly high (Fig. 2) [14, 15].

Training of specialists providing ophthalmological care during the stages of medical evacuation. To provide qualitative ophthalmosurgical care the specialists have to be experienced in eye traumas. In peacetime military ophthalmologists face eye trauma not more often than civilians [16]. Staying one-to-one with real wounded people while performing their tasks in conditions that significantly differ from a well-equipped ophthalmological hospital, the specialists experience objective difficulties in diagnosing, determining the tactics of patient management, performing surgical treatment of eye wounds of different localization [17].

In this regard, it seems necessary to pay attention to an additional training program for ophthalmologists in terms of mastering and developing practical skills of surgical treatment of wounds of the eyeball and its accessory organs. It is advisable to implement such a training course in the conditions of a training operating room on cadaver pig eyes (WetLab format), with simulation of different types of open eye trauma, accompanied by lectures highlighting the basic principles of diagnosis and treatment of combat eye trauma [18–20]. It is also important to include simulations of situations in which an operating microscope is not available and surgical treatment is performed with the naked eye or using binocular ophthalmic magnifying glasses with magnification.

Medical supply of the units deploying the stages of medical evacuation with ophthalmic equipment. Another cornerstone of providing ophthalmological care at the stages of medical evacuation is the issue of medical supplies. At the admission of patients with open eye trauma an ophthalmologist performs rather limited scope of surgical aid: primary surgical treatment of corneal and scleral wounds the main aim of which is eyeball sealing as a variant of transport sealing - along with blepharorrhaphy, conjunctival covering and soft contact lenses application [6, 7, 21].

The optimum visualization tool is undoubtedly the operating microscope, but it is not always available. In its absence, we used binocular dental magnifying glasses with x3.5 magnification and focal distance of 420 mm equipped with an autonomous light source, which allowed us to work comfortably for a long time and obtain more satisfactory visualization during scleral wound sealing as

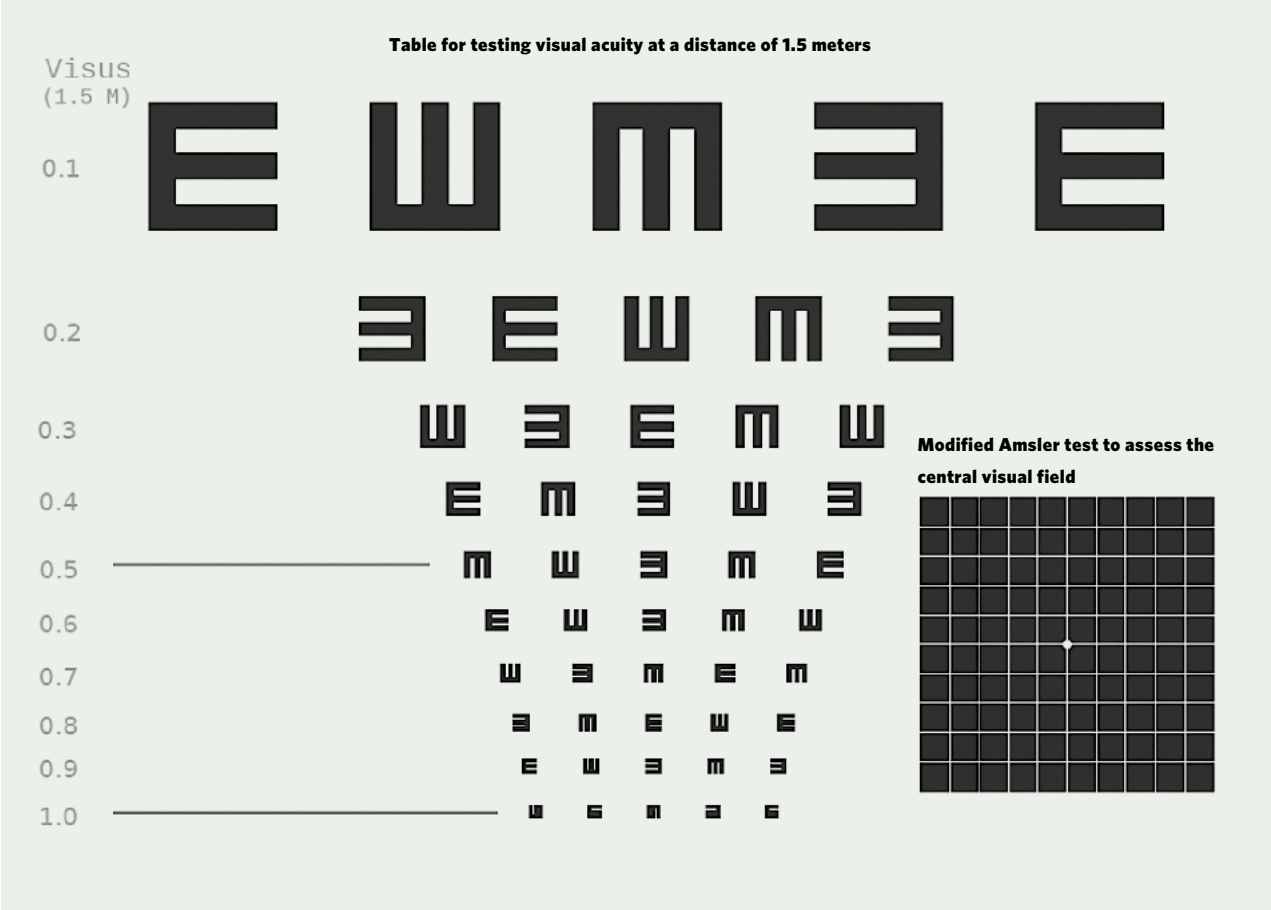

Fig. 3. The table for testing visual acuity at a distance of 1.5 m developed by Koskin S.A., Khlebnikov V.V., Shelepin Y.E. [26]

well as during surgical treatment of wounds of accessory organs than if we used a binocular head magnifier (LBN-2.5), which was on supply. At the same time, it seems technically extremely difficult to suture complex corneal wounds with a 10/0 thread in the absence of an operating microscope. In such conditions, the wound is sutured with suture material of conditional size 8/0 with forced neglect of the rules of corneal wound sealing, which results in insufficient tightness, high level of incorrect induced astigmatism, which later is difficult to be corrected [22–25].

There is also a question about the necessity of the Golovin-Sivtsev table with the cumbersome Roth apparatus in conditions of massive admission of victims, when visometry is required mainly at the stage of medical triage in the admission ward. In our opinion, in such conditions it is reasonable to use a table for visual acuity testing at a distance of 1.5 m, which is placed in a robe pocket [26, 27] (Fig. 3).

Modern eye protection equipment. Modern equipment for individual eye protection included in the kit "Ratnik", such as anti-shrapnel goggles 6B50, have high safety standards, so they can resist serious impacts of wounding projectiles [28]. However, they are not always used correctly and in a timely manner by personnel due to their unwieldiness, difficulty in releasing the lenses from the case at the right moment, or their periodic fogging during prolonged use and limited visualization of the perimeter through them. Therefore, in addition to a high level of protection, it is essential that the glasses also be anti-fog, have a comfortable and functional design and do not distort the image, restrict the field of vision or cause contrast sensitivity impairment [28–31].

In the process of transporting victims to the medical evacuation phase, there remains a risk of exacerbating the injury when measures for protecting the injured eye are not taken or are inadequate.

Fig. 4. Severe contusion of the right eyeball, right eye socket with retrobulbar hematoma, pronounced exophthalmos, chemosis, and lagophthalmos. After removal of the pressure binocular dressing, the ocular surface showed areas of conjunctival necrosis, complete corneal de-epithelization

In Russian military ophthalmology, a binocular dressing is recommended for open eye trauma and severe contusions, which provides "immobilization" of the injured eye by depriving both eyes of visual stimuli and creating rest to the injured eye [6, 21]. In some cases, for example in lagophthalmos, when intraocular membranes protrude into the ocular cleft, the dressing contributes to additional eye trauma. Pressure dressings applied on the battlefield are indicative in this regard (Fig. 4) [32]. Besides, the dressing in contact with the eye also contributes to absorption of the leaking intraocular fluid and progression of hypotension in its perforated wounds.

According to the canons of military medicine in Western countries, it is strictly forbidden to put dressings on the injured eye in order to avoid its additional trauma [33]. A rigid eye shield, recommended for application, does not touch the eye and is necessary to prevent additional impacts on it during evacuation [34, 35]. At the same time, such approach does not contribute to "immobilization" of the injured eye during its active movements, so the work of oculomotor muscles can cause potential harm in perforated scleral wounds with intraocular membrane prolapse.

One likely solution is to apply a binocular patch so that the injured eye is protected by an eye shield under the patch and the healthy eye is covered by the patch. This option combines the advantages and mutually compensates for the disadvantages of both methods. This approach to desmurgy for open eye trauma should be practiced in pre-hospital self-aid, mutual-aid, and first-aid training.

The increase of eye trauma frequency in the conditions of armed conflicts of the beginning of the 21st century, the increased percentage of binocular injuries, traumatization of young people of working age dictate us to take serious measures to improve the situation. Guided by changes in the nature of combat operations and the work of medical units, as well as advances in medical technology, it is advisable to review the equipment of medical equipment of units deploying stages of medical evacuation for quality work of the ophthalmologist. At present it is advisable to use modern compact models with increased autonomous operation time. For quality training of ophthalmologists in the field of ocular trauma, effective programs for mastering practical skills in the surgical treatment of open eye trauma are needed

Conclusions. At critical moments in history, which include armed conflicts, it is extremely important to discuss, analyze issues and problems of military medicine, share experience and generalize it.

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70 years of the neurosurgical clinic of the Hospital named after N.N. Burdenko. Accumulated experience in the treatment of gunshot wounds of the central and peripheral nervous systems

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Abstract. The article highlights the historical aspects of the origin of neurosurgery as a specialty within the walls of the Main Military Clinical Hospital named after Academician N.N. Burdenko. Based on the clinical experience of the neurosurgical center, the principles of diagnosis and surgical treatment of gunshot wounds of the central and peripheral nervous systems are described.

Keywords: neurosurgical care, gunshot wounds, academician N.N. Burdenko, the first neurosurgical department of the Soviet Army.

Introduction. Since 1933 up to the end of the Great Patriotic War the consultant-surgeon of the hospital was an outstanding scientist, surgeon, public health organizer, state and public activist, the first Chief Surgeon of the Red Army, the first President of the Academy of Medical Sciences (AMS) of the USSR Nikolay Nilovich Burdenko. He provided comprehensive consulting, surgical and organizational assistance to the 1st Moscow Communist Military Hospital (since 1944 - the Main Military Hospital of the Red Army), most of his time being devoted to the wounded of the neurosurgical profile. As the chief surgeon of the Main Military Hospital (MMH) named after Academician N.N. Burdenko wrote. N.N. Burdenko A.I. Makarenko, who was at that time the Head of one of the surgical departments of the hospital, "Nikolai Nilovich always demonstrated his deep knowledge and wide experience while solving diagnostic and treatment issues, he tried to help the diseased and injured by applying optimum surgical treatment". Displaying his high humanism, the eminent surgeon always strived for "saving" and organ-preserving treatment. The patients suffering from traumatic injuries of the skull, spine and peripheral nerves were operated on in the hospital, the skull defects were replaced, neurolysis and nerve suturing were carried out. With N.N. Burdenko's participation removals of brain tumors were being performed.

"Even before the beginning of the Great Patriotic War, Nikolay Nilovich Burdenko cherished the hope to organize neurosurgical aid directly in the hospital, — wrote the chief of the MMH named after N.N. Burdenko A.M. Krupchitsky in his book "The Firstborn of Russian Medicine". — This was accomplished five years after his death".

In November 1952 the first in the Soviet Army specialized 22nd neurosurgical department with 30 beds was opened in the hospital [1], which was created and headed by a student of N.N. Burdenko — an experienced neurosurgeon and organizer Nikolay Petrovich Bazhenov.

Then in 1960 he was replaced by G.M. Chugunov, a senior resident of the department, who had by that time passed a training course Research Institute of Neurosurgery named after Acad. N.N. Burdenko. In the following years, there was a steady increase in the number and complexity of surgical interventions on the brain and spinal cord, new methods of diagnosis and treatment were mastered: pneumoencephalography (1960) was introduced into the practice of the department; nitrous oxide anesthesia was used in neurosurgical operations (1960-1961); angiography of cerebral vessels was implemented. Specialists of the department successfully performed surgeries on the large cerebral hemispheres, cerebellum, base of the brain, pituitary gland, chiasmal region, brain ventricles, spinal cord, in the area of the cerebellopontine angle, and the indications for surgical interventions for consequences of inflammatory processes (arachnoiditis, occlusion of liquor ducts) and prolapse of intervertebral discs were expanded.

In 1974 after the untimely death of G.M. Chugunov, colonel of the medical service B.G. Tsehanovsky was appointed the Head of Department, under whose supervision the surgeries on the cerebral vessels were performed, and the operations on the cerebral vascular aneurysms were performed for the first time in the hospital. In 1980s the department widely introduced the method of microsurgery in operations on brain, spinal cord and peripheral nerves and mastered the method of active surgical treatment of brain contusions with the removal of contusion centers. In 1982 the 22nd Department performed one of the first operations in the Armed Forces on applying anastomoses between one of the branches of the main cerebral arteries and the arteries of the soft integuments of the head.

From 1989 to 2005 the 22nd neurosurgical department of the hospital was headed by colonel of the medical service Shchigolev Y.S., who since 1981 had worked his way forward in the Main Military Hospital from an intern to the head of the department, and later - the head of neurosurgical center organized under his leadership and Deputy Chief Neurosurgeon of Russian Federation Ministry. Prof. Shchigolev is an honored doctor of the Russian Federation, the author and co-author of more than 100 scientific publications in Russian and foreign editions, textbooks for students of medical high schools and manuals for doctors. In performing his military and medical duty, he rendered emergency neurosurgical aid in the most different places of the globe [2].

In 2005, the 22nd neurosurgical department was reorganized into a neurosurgical center with four bed wards, an operating department, and an ophthalmology cabinet [3].

Since 2009 and up to now the neurosurgical center of the Main Military Clinical Hospital (MMCH) named after N.N. Burdenko has been headed by Shamil Khambalovich Gizatullin. Shamil Khambalovich Gizatullin, honored doctor of the Russian Federation, doctor of medical sciences, member of Moscow, Russian and international neurosurgical societies. He took an active part in rendering specialized neurosurgical aid in "hot spots": in Tiraspol (1992), Vladikavkaz (1992), Dushanbe (1993), Mozdok (1994-1995). The result of the analysis of the experience of treatment of hundreds of victims and wounded in the zones of local conflicts was the writing of doctoral dissertation "Traumatic disease in gunshot wounds and cranial and brain injuries (clinical picture, diagnostics, treatment, complications, outcomes)" in 1999.

The neurosurgical center actively develops minimally invasive neurosurgery, applies new methods of treatment and diagnostics, actively carries out rationalization work, regularly conducts training master classes for neurosurgeons. Every year the hospital hosts scientific-practical conference "Burdenko Meetings", where distinguished experts in world neurosurgery give speeches, they discuss up-to-date problems and ways of their solution, experience exchange takes place and scientific-practical relations between civil and military healthcare institutions are strengthened. In addition, the center started postgraduate educational activities, accepting in 2021 the first residents in the specialty "Neurosurgery". Implementation of the training program is supported by guidance documents and material and technical equipment, including a simulation room where resident physicians practice their microsurgical skills on a daily basis. However, continuing the tradition established by Nikolay Nilovich Burdenko, the main training takes place "at the patient's bedside.

Currently, the Burdenko Neurosurgical Center is one of the leading neurosurgical clinics in Russia. Every year we perform more than 1,500 operations on the brain and spinal cord, spine and peripheral parts of the central nervous system. Our vast experience in the treatment of vascular pathologies, brain and spinal cord tumors, herniated intervertebral discs, spinal stenosis and listhesis allows us to choose the optimal and minimally invasive way to treat our patients. Modern methods of treating degenerative diseases of the spine, such as transpedicular systems, interbody implants, and total discectomy with anterior access, ensure the flagship position of our clinic in the modern world of neurosurgery.

At the same time, the main task of the neurosurgical service of the MMCH named after N.N. Burdenko remains to provide and improve specialized neurosurgical care to the patients with injuries and wounds of skull and brain, spine and spinal cord, peripheral nerves. Today, the participation of neurosurgeons with such profound experience is necessary in the process of providing highly qualified medical care to the victims of mass disasters and military conflicts.

Table 1. Distribution of head wounds by type of injury in modern military conflicts, %

Types of wounds	War in Afghanistan 1979–1989 years	Armed conflicts in the Caucasus		
		1994–1996 years	1999–2002 years	2008 year
Isolated	26,5	32,4	15,8	30,8
Multiple	10,7	8,2	7,2	0
Combined	62,8	59,4	77,0	69,2
TOTAL	100,0	100,0	100,0	100,0

Table 2. Distribution of patients wounded in the head according to the nature of wounds in modern military conflicts, %

Character of wounds	War in Afghanistan 1979–1989 years	Armed conflicts in the Caucasus		
		1994–1996 years	1999–2002 years	2008 year
Soft tissues	68,2	51,2	61,1	30,8
Non-penetrating skull wounds	13,1	21,9	15,4	53,9
Penetrating skull wounds	18,7	26,9	14,5	15,4
TOTAL	100,0	100,0	100,0	100,0

In 1980s the department widely introduced the method of microsurgery in operations on brain, spinal cord and peripheral nerves and mastered the method of active surgical treatment of brain contusions with the removal of contusion centers. In 1982 the 22nd Department performed one of the first operations in the Armed Forces on applying anastomoses between one of the branches of the main cerebral arteries and the arteries of the soft integuments of the head

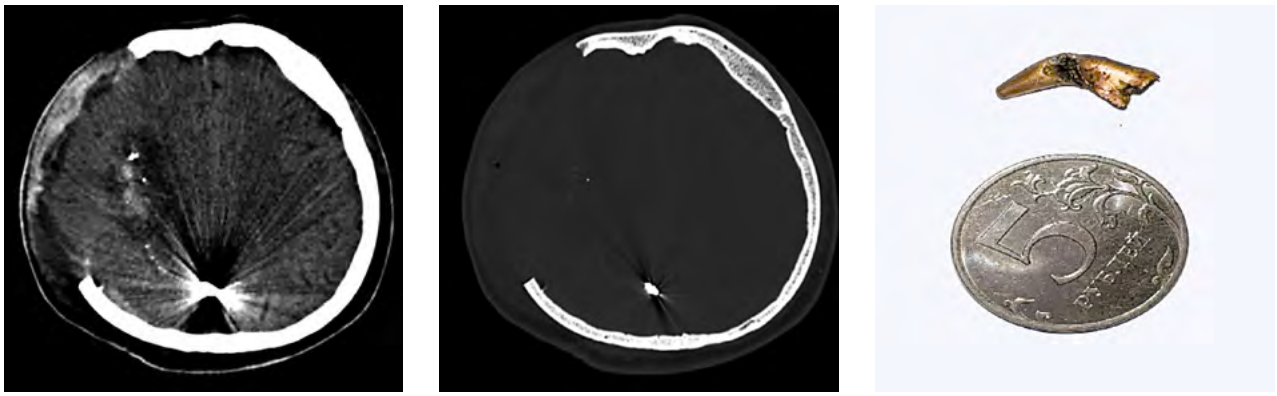
Experience in the treatment of craniocerebral gunshot wounds. In modern military conflicts neurosurgical casualties are as high as 30%, craniocerebral injuries account for 12%, of which 42% are blast injuries, 15% are gunshot wounds (8% are shrapnel wounds, 7% are bullet wounds), and 43% are non-gunshot injuries [4].

According to an analysis of head wounds obtained in twentieth- and twenty-first-century armed conflicts, the incidence of isolated wounds was 15.8–32.4 percent of cases, and of combined was more than half of all cases (Tables 1 and 2) [5].

Treatment of gunshot craniocerebral wounds is a complex task because any penetrating projectile causes primary brain injury, the severity of which depends on ballistic properties, mass of the wounding agent, velocity, shape, angle of entry, tissue characteristics, etc., as well as secondary injury resulting from secondary wounding elements, such as bone or metal fragments. At the same time, projectiles with higher velocity cause additional injury to brain tissue due to the cavitation effect, which in turn causes air, skin and hair to be sucked into the brain parenchyma, which contributes to the development of severe infectious complications.

Various neuroimaging techniques are used to verify the nature of a gunshot cranial injury and surgical planning, assessing:

- entrance and exit wounds;
- presence of intracranial bone fragments and foreign bodies;
- trajectory of the projectile and its connection with cerebral vessels, nerves, and sinuses of the skull base;



A B C

Fig. 1. Native CT scan of the brain in a gunshot segmental brain injury: A — wound channel of the right cerebral hemisphere with hematoma along its path and a foreign body in the occipital lobe, post-trapanation skull defect; B — CT scan in bone mode, a distinctive signal from a metal foreign body is seen; C — extracted deformed bullet cartridge

- presence of pneumocephaly;
- transventricular damage;
- condition of basal cisterns;
- presence of dislocations;
- character of brain parenchyma lesions (mass-effect, cerebral edema, intracranial hematomas).

The use of computed tomography (CT) allows a full assessment of the condition of the brain and the nature of the wound, and the ability to perform CT with the presence of foreign bodies and its rapidity makes this method of examination the "gold standard" in the diagnosis of gunshot wounds (Fig. 1)

Angiography is indicated for projectile trajectory in the projection of main arteries and brain sinuses, as it allows timely diagnosis and treatment of delayed vascular complications [6]. CT angiography has many advantages over traditional digital subtractive angiography. However, artifacts from metallic foreign bodies can impede adequate visualization of intracranial vessels.

Magnetic resonance imaging (MRI) carries potential hazards because ferromagnetic projectiles can cause additional injury, and therefore MRI is not recommended for use in gunshot wounds. However, in some cases, to assess the effects of wounds under certain conditions, MRI provides additional clinically meaningful information about the condition of the brain.

The surgical treatment of gunshot brain wounds is controversial among many neurosurgeons. Some favor minimal and gentle surgical treatment with preservation of as much brain tissue as possible, while other neurosurgeons use aggressive tactics trying to remove all bone and metal fragments [7].

Our experience shows that the tactics and volume of surgical aid should be personalized. On the one hand, not removed bone fragments and metal foreign bodies may be associated with a higher risk of infectious complications, on the other hand, there are studies, according to which there was no correlation between the presence of remaining foreign bodies and the subsequent development of intracranial infection or epilepsy [8].

Thus, many factors should be considered in determining the indications for surgical treatment, including ballistic features of the wounding projectile, age and condition of the patient, and CT scan data. We use the algorithm shown in Figure 2.

Surgical treatment of gunshot wounds includes irrigation, debridement of nonviable tissues, removal of volumetric hematomas, depressed bones and accessible bullet fragments. In the presence of dislocation, mass effect with a shift of more than 5 mm or flattening of the basal cisterns by diffuse edema or hematoma, resection craniotomy of an area sufficient for decompression with the use of dura mater expansion plasty is indicated. In the absence of mass effect surgical treatment of the wound canal is not recommended. In case of cranial sinus wounds, their cranialization and subsequent sealing is necessary. If there is wound liquorrhea, it should be eliminated as soon as possible using available methods.

Experience in the treatment of gunshot spinal cord injuries. In modern military conflicts, spinal cord injuries account for 0.5–2.4% in the overall structure of combat surgical trauma [4]. According to Petrov Y.N., the incidence of isolated spinal wounds was 2.9–17.4% of cases, and the incidence of combined wounds was 82.6–97.1% of all cases (Tables 3 and 4) [5].

The severity of spine and spinal cord injuries depends on the ballistics of the projectile, the character of the wound, the degree of spinal cord injury, the presence of spinal cord compression by hematoma or bone fragments, and the mechanical stability of the spine.

Computed tomography, as in gunshot wounds, is the main method of diagnosing spinal cord and spinal cord

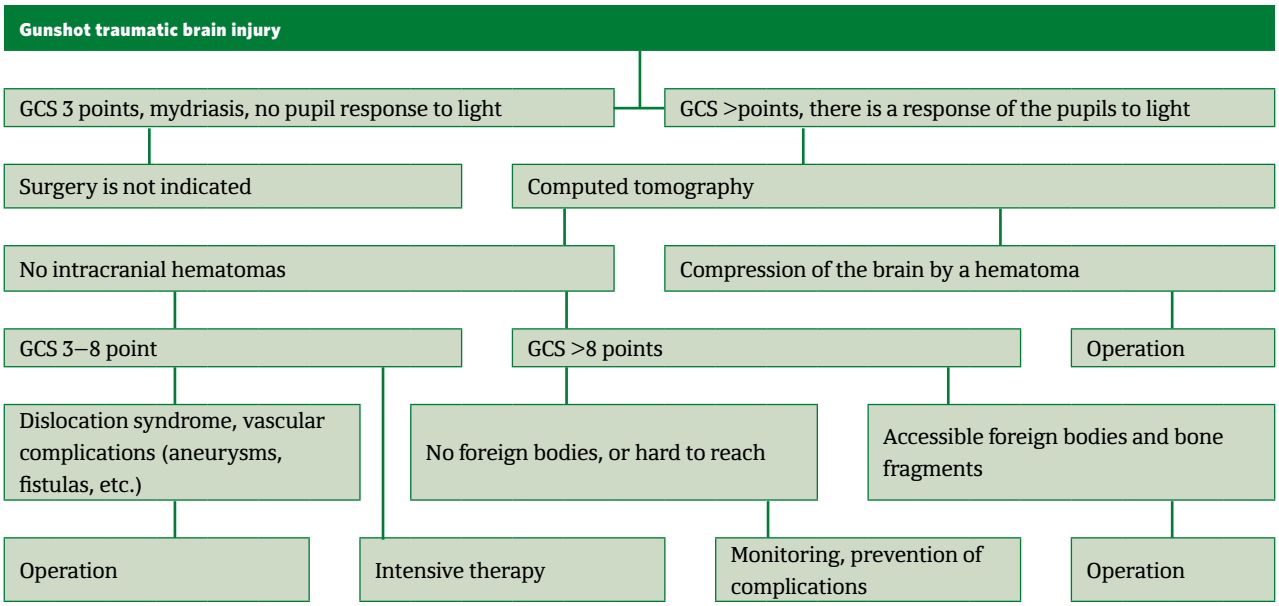


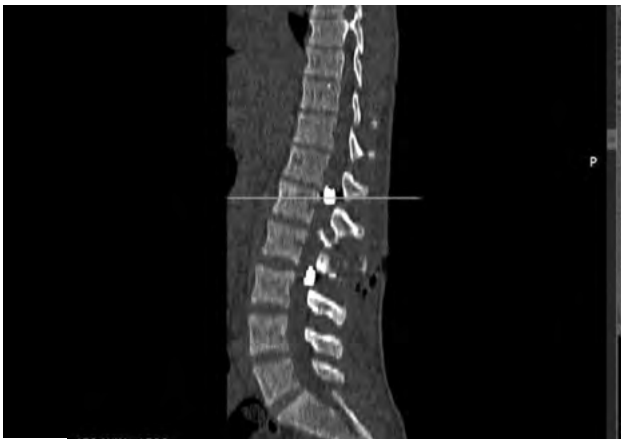
Fig. 2. Algorithm and tactics of surgical treatment of gunshot wounds of the brain

Table 3. Distribution of spinal cord injuries by type of injury in modern military conflicts, %

Types of wounds	War in Afghanistan 1979–1989 years	Armed conflicts in the Caucasus		
		1994–1996 years	1999–2002 years	2008 year
Isolated	14,8	17,4	2,9	17,4
Multiple	0	0	0	0
Combined	85,2	82,6	97,1	82,6
TOTAL	100,0	100,0	100,0	100,0

Table 4. Distribution of wounded in the spine according to the nature of wounds in modern military conflicts %

Character of wounds	War in Afghanistan 1979–1989 years	Armed conflicts in the Caucasus		
		1994–1996 years	1999–2002 years	2008 year
Paravertebral	26,6	21,7	11,8	100,0
Non-penetrating	40,7	43,5	52,9	0
Penetrating	32,7	34,8	35,3	0
TOTAL	100,0	100,0	100,0	100,0



A

B

Fig. 3. HNative CT scan of the spine for a shrapnel penetrating wound of the spine: two foreign metal fragments in the spinal canal at the level of L1 and L3 vertebrae

injuries, and additionally provides valuable information about the severity of associated pathology (Fig. 3). CT myelography is a good method of diagnosing the level of liquorrhea. Functional radiography assesses the mechanical stability of the spine.

Treatment of vertebrospinal injuries depends on the neurosurgeon's understanding of the mechanism of injury, analysis of prognostic mechanical and biological factors, diagnostic imaging, and understanding of management tactics for such patients. Initially, a complete neurological examination and history should be performed. Tetanus prophylaxis and prescription of broad-spectrum antibiotics should not be forgotten, regardless of the site of injury. Given the lack of efficacy, steroids should not be included in the treatment regimen for spinal cord injuries. Decisions on surgical treatment and its timing depend on neurological status, spinal stability, bullet location and level of injury, presence of liquorrhea, presence of lead intoxication, and probability of foreign body displacement.

When it is difficult to verify the severity of the injury, early revision can reliably assess the condition of the nerve and create favorable conditions for recovery or perform primary restoration of nerve integrity

In our practice, we use the treatment tactics for gunshot vertebrospinal wounds presented in Fig. 4.

Experience in the treatment of gunshot wounds of the peripheral nervous system. In local armed conflicts, nerve injuries account for 10.9–12.0% in the total structure of combat surgical trauma [4]. Nerve injuries in gunshot wounds are caused by multifactorial mechanisms: direct trauma, indirect impact due to shockwave cavitation and thermal damage, and often nerve injuries are accompanied by combined damage to vessels, bones and tendons of the extremities. Defects of nerve trunks after gunshot wounds are 5 cm or more in the vast majority of cases.

Diagnosis begins firstly with neurological examination, documentation of motor, sensory and autonomic disorders. Electroneuromyography during the first weeks is not informative due to ongoing Wallerian degeneration. MRI due to the presence of foreign bodies is not performable. The resolution of CT does not allow assessing the extent of nerve damage. Therefore, the method of choice for diagnosis of gunshot wounds of nerve trunks is ultrasound examination (ultrasound), which has high specificity and sensitivity. When it is difficult to verify the severity of the injury, early revision can reliably assess the condition of the nerve and create favorable conditions for recovery or perform primary restoration of nerve integrity.

Primary reconstruction of the nerve in gunshot wounds is contraindicated. During primary surgical treatment, if a complete nerve rupture is found, its ends should be marked (not excised) with non-absorbable monofilament or provisory sutures, maintaining the correct angular position as much as possible. These ends should be placed away from the damaged soft tissue and bone, thus preventing excessive neuroma formation. If possible, the treated ends should be placed in a tube of inert material (silastic or silicone catheter) to prevent adhesions from forming with the surrounding damaged tissue. Then after 1–3 months the reconstruction of the nerve trunk is indicated (Fig. 5).

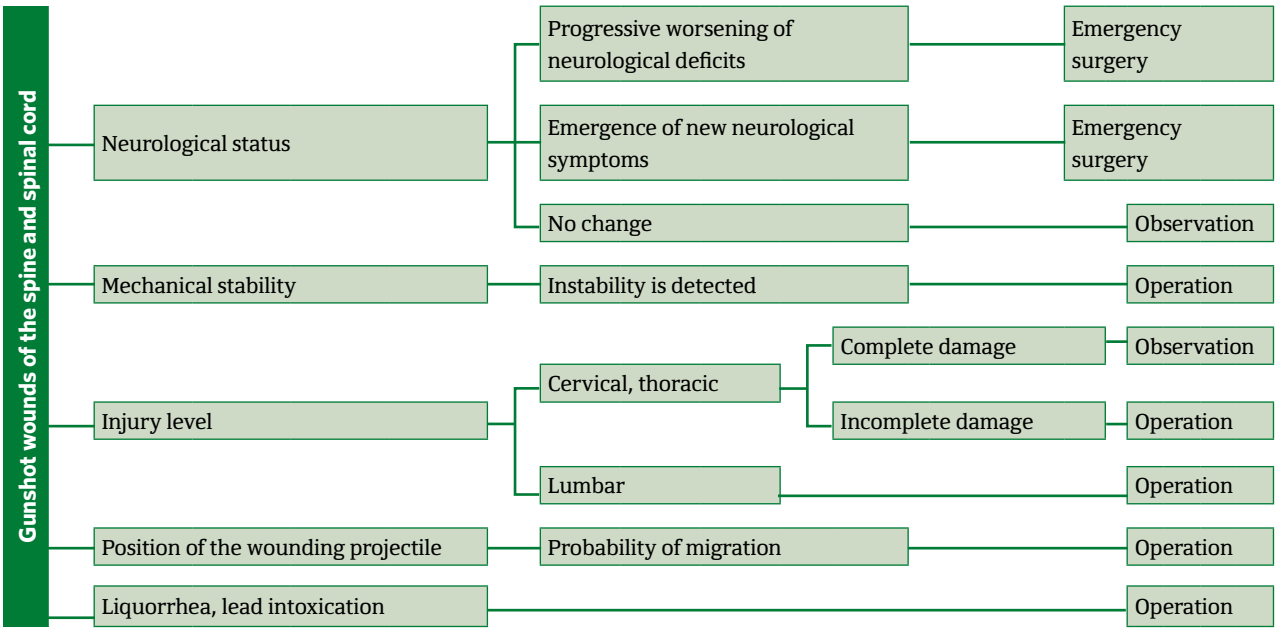
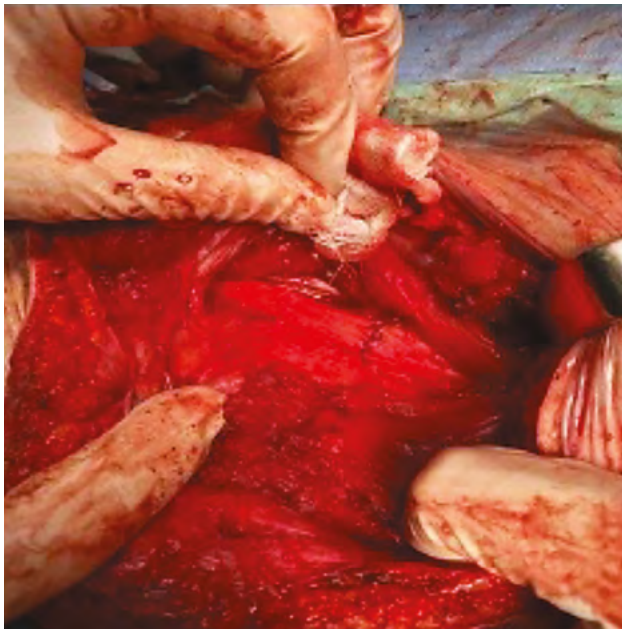


Fig. 4. Algorithm and tactics of surgical treatment of gunshot wounds of the spine and spinal cord

A



B

Fig. 5. Intraoperative photographs of gunshot injury of the sciatic nerve at the level of the middle third of the femur: A — demonstration of the terminal neuroma (after excision, the diastasis was 2.5 cm); B — epineural suture

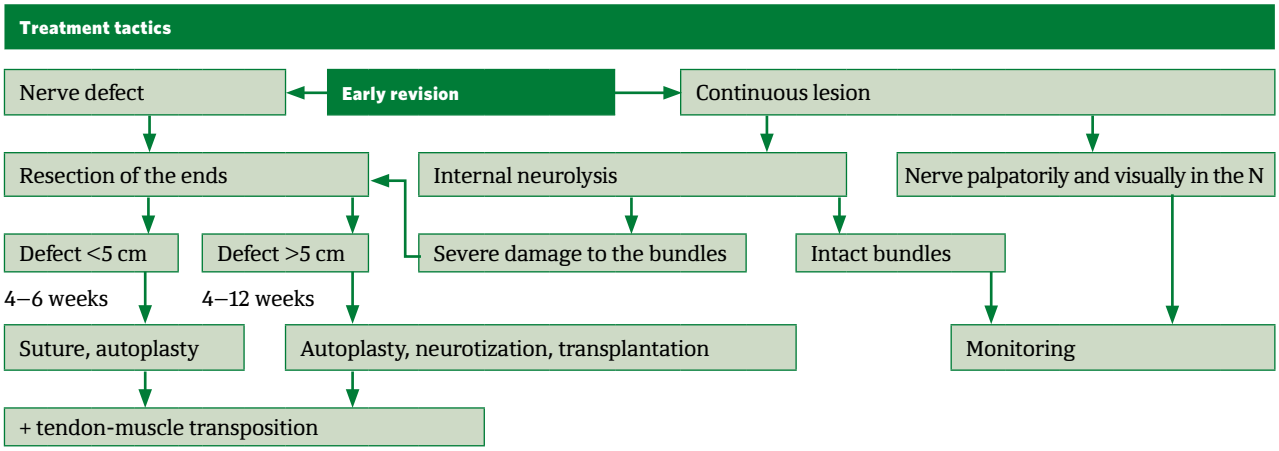


Fig. 6. Algorithm and tactics of surgical treatment of gunshot wounds of nerve trunks during early revision

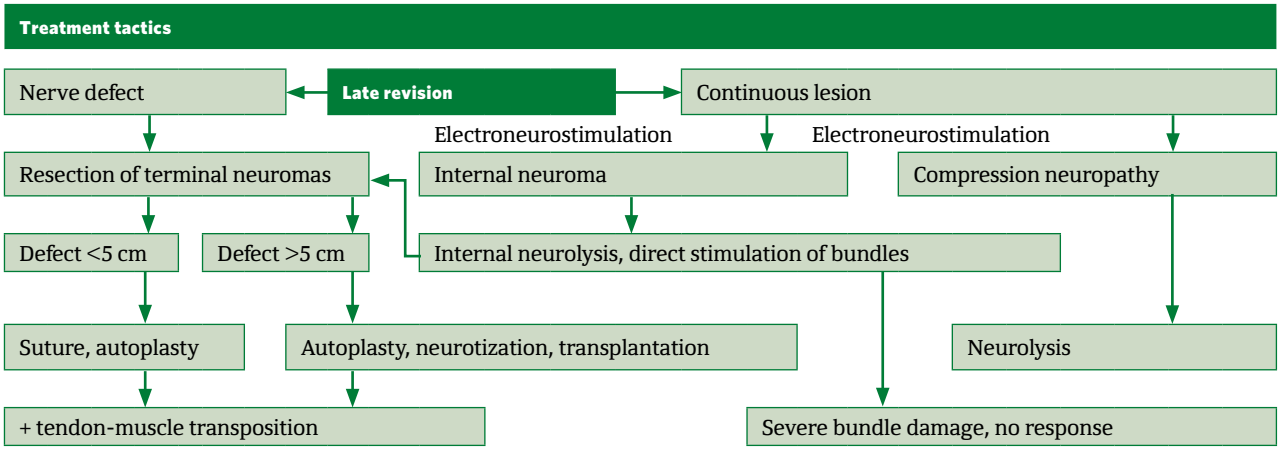


Fig. 7. Algorithm and tactics of surgical treatment of gunshot wounds of nerve trunks in delayed and late revision

Based on the accumulated experience, our center proposes and uses the tactics for the management of wounded patients with nerve trunk injuries presented in Figures 6 and 7.

Conclusion. With changes in the conditions of wars and armed conflicts the nature and structure of wounds to the central and peripheral nervous system are also changing. Despite the use of modern protective equipment, the lethality of such injuries remains high. The decades of experience in providing neurosurgical care in armed conflicts, the system of specialist training and continuity, the use of advanced treatment methods and innovative technologies, the modern equipment of the neurosurgical center allow us to provide medical care at the highest level.

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Principles of intensive therapy for gunshot wounds of the skull and brain

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Abstract. With the modern development of battlefield medicine and air ambulance evacuation, the quality of medical care is undergoing changes. As for neurosurgical combat trauma, the provision of medical care for this patient population requires more specialization, closer to the front line and reduction of stages. The article summarizes the results of experience in the treatment of gunshot wounds to the head. The severity of injuries to the skull and brain on admission was assessed using the Injury Severity Score. The condition of 67% of those admitted was considered severe, the mortality rate was 0.8%, and the length of stay in the intensive care unit was 12 days. Extremely severe were 33% of the wounded, the mortality rate in this group was 2.2%, and the length of stay in the intensive care unit (ICU) was 31 days. When assessing the level of consciousness at our stage on the Glasgow coma scale, most of the wounded had a score of 6–8, which corresponds to a deep coma. Direct evacuation of the wounded to the specialized stage of care, computed tomography (CT), availability of a qualified neurosurgeon, the earliest possible decompressive craniotomy if indicated are the components of success in dealing with intracranial hypertension, the development of subsequent neurological deficit and reducing mortality. Nutritional support and antibiotic therapy are important components of intensive care in neuroresuscitation.

Keywords: cranial gunshot wounds, air medical evacuation, intensive care, intracranial hypertension, nutritional support, decompressive craniotomy, meningoencephalitis, antimicrobial therapy.

Introduction. In modern local wars and armed conflicts, the possibilities of individual approach to the treatment of the wounded are limited, since at different stages of evacuation they are each time operated on by different surgeons. Therefore, a "military field medical doctrine" is a kind of a law for military medicine, which includes unified views on the principles of treatment and evacuation. For these purposes there are special purpose medical detachments, surgical unit (airmobile), non-staff teams of specialized medical aid [1, 12]. The principle still prevails in the system of medical aid to the wounded: evacuation in the first place. An active participant of the First World War and the Civil War V.A. Oppel defended the idea of early surgical interventions in the treatment of gunshot wounds [1, 7], at the same time N.I. Pirogov in his works indicated that "evacuation is a necessary yet inevitable evil for a wounded person", understanding that no matter how gently the transportation was performed, the wounded person's condition would get worse. This statement has been confirmed in the works performed in the course of air ambulance evacuation (AAE) of the wounded from the battlefield up to strategic evacuation to the rear medical institutions with the use of medical modules. The influence of negative factors of flight, the most important of which is hypobaric hypoxia, was substantiated [2]. The peculiarities of medical care for wounded servicemen in Syria (2015 — present) were: improvement of pre-hospital care due to the improvement of medical equipment and wide use of tactical and strategic AAE of seriously wounded to the central medical treatment military-medical organizations during the first day after the wound [1, 2].

Advances in military field surgery, anesthesiology and resuscitation based on new organizational solutions, maximum implementation of modern technologies and therapeutic tactics of peacetime surgery have led to a significant improvement in the results of combat trauma treatment [1, 3, 7, 12].

Changes in the structure of casualties in terms of localization of wounds in modern local wars and armed conflicts, compared to the Great Patriotic War, are mainly reduced to an increase in the proportion of head and limb wounds, as well as an increase in the number of mine blast injuries of the brain. Moreover, the severity of such wounds is caused by their combined character: along with the lesions of the central nervous system (CNS) there are lesions of other organs and body systems, and the resulting syndrome of mutual aggravation, typical for this type of wounds, exacerbates the condition of the wounded [3, 4, 8].

Thus, the structure of medical losses in terms of the number and severity of wounds in local wars has changed in the direction of increasing the proportion of severe injuries. This is largely due to improved pre-hospital care and shorter evacuation times of the wounded from the battlefield to advanced hospitals. The basic principle of military field surgery in relation to the head wounded is to deliver them as quickly as possible to the stage of specialized care to the neurosurgeon, bypassing the previous stages of medical evacuation, for accurate topical diagnosis of craniocerebral injury (CT scanning is optimal), surgical treatment and intensive care using all necessary modern technologies [1, 2, 8]. At the stage of skilled care, surgical aid should be provided only for penetrating and non-penetrating cranial wounds with ongoing external bleeding [1, 2, 12]. Despite significant progress in the treatment of the wounded, some issues of neurosurgical care organization and intensive care of head wounds remain unresolved.

Objective of the study. To analyze the effectiveness of intensive therapy of cranial and cerebral wounds and to determine the treatment tactics for this pathology at the stage of specialized high-tech medical care.

Material and methods. The anesthesiology-resuscitation department of the neurosurgical center of the of the Main Military Clinical Hospital (MMCH) named after academician N.N. Burdenko of Ministry of Defence treated the wounded patients with the leading head and spinal cord wounds. Of the total number of head wounded, isolated injuries to the skull and brain were in 41%; injuries to the brain, facial skeleton, and eyes in 21%; to the brain, limbs, and pelvis in 26%; and to the brain, chest in 12% (Fig. 1).

41%	Isolated injuries to the skull and brain
26%	Brain, limbs, pelvis
21%	Brain, facial skeleton, eyes
12%	The brain and the chest

Fig. 1.
Structure of the wounded with skull and brain injuries. Brain wounds

Table 1. ISS Scale of Injury Severity

Type of wound	Severe injury 16-24 scores (mortality 5-7%, length of stay in ICU 8-10 days)			Extremely severe injury more than 24 scores (mortality 30%, length of stay in ICU more than 12 days)		
	%	Lethality, %	Bed-day, days	%	Lethality, %	Bed-day, days
Brain injuries	67	0,8	12	33	2,12	31
Spinal cord injuries	12	0	10	78	0	17

Table 2. Glasgow Coma Scale for assessment of physiological disorders

Level of consciousness in scores	Clear 15	Moderate stun 13-14	Deep stun 11-12	Sopor 10-19	Moderate coma 8-7	Deep coma 6-5	Atonic coma 4-3
%	3,4	5,8	12,2	17,3	40	13,3	8

Table 3. Energy requirements (indirect calorimetry) and nitrogen losses in isolated and combined cranial and brain wounds

Condition	Energy requirements, kcal/kg/day	Nitrogen losses, g/day	Nitrogen balance, g/day
Isolated cranial and brain wounds	34–39	19–23	-9–11
Combined wound	36–50	30–35	-17–19

The severity of injuries to the skull and brain on admission was assessed using the Injury Severity Score (ISS). In 67% of the admitted patients the condition was considered severe, the lethality rate was 0.8%, the length of stay in the intensive care unit was 12 days. In the extremely severe condition were 33% of the wounded, the lethality rate in this group was 2.2%, and the length of stay in the ICU was 31 days (Table 1).

When assessing the level of consciousness on the Glasgow Coma Scale (GCS), most of the wounded had a score of 6-8, which corresponds to a moderate coma (Table 2).

It should be noted that almost 100% of the wounded upon admission were in hypovolemia, hypernatriemia, and hypoproteinemia. Further instrumental examination in 44% of the wounded diagnosed polysinusitis, which required puncture and debridement of maxillary sinuses. Bronchoscopy findings revealed normal tracheobronchial tree in 13% of the wounded, diffuse endobronchitis of 1st grade inflammation intensity in 17%, and diffuse endobronchitis of 2nd grade inflammation intensity with purulent-hemorrhagic component in 70%, with aspiration signs in this group in 9% of cases.

Results and discussion. The main task of intensive therapy in the wounded with cranial and brain injuries is the prevention of hypoperfusion and hypoxia, aimed at combating secondary brain damage [5, 6]. This task should be performed not only in the hospital, but also at all stages of evacuation of a wounded person, from the very beginning of his medical care. Maintenance of continuity at all stages of evacuation is the key to successful clinical outcome [2]. The mean arterial pressure in brain injury should not be below 90 mm Hg (considering the preserved autoregulation), as the cerebral perfusion pressure, determined by the formula, directly depends on this value:

CPP=APm – IP,

where: CPP — cerebral perfusion pressure; APm — mean arterial pressure; IP — intracranial pressure, which without monitoring should be considered equal to 20–25 mm Hg. [5, 6, 9].

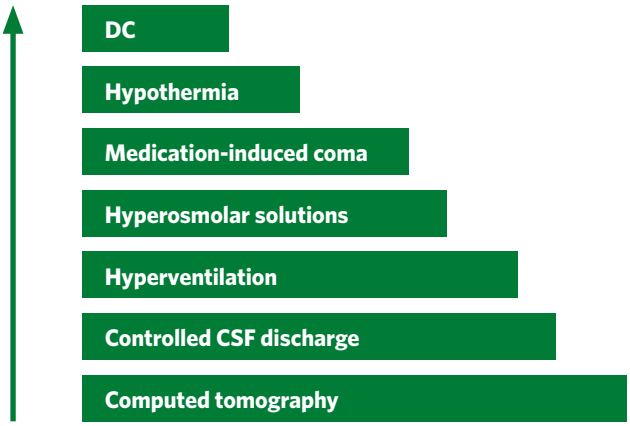

Fig. 2. Stepwise algorithm of intracranial pressure control

When preparing a wounded person for AAE, it should be taken into account that the condition may worsen when exposed to hypobaric hypoxia [2]. Particular attention should be paid to assessing the level of consciousness in the wounded with brain damage. If the level of consciousness on the Glasgow Coma Scale is less than 9 scores and there are clinical signs pointing out that it may worsen, such a wounded person should be intubated and evacuated on artificial lung ventilation. At the same time, sedation, anesthesia and neurovegetative protection should be carried out in full under monitoring of vital signs, such as AP, heart rate (HR), capnometry, SpO_2.

Decompressive craniotomy (DC) in the stepwise algorithm of IP control (Fig. 2) [3, 6] when providing neurosurgical care to a wounded person and preparing for AAE should not be at the top of the algorithm. With mine blast injuries of the brain, adequate decompression is the key to successful treatment, since it provides not only IP prevention, but also debridement of the lesion site. As a result, decompression is almost the first line of treatment when a wounded person is admitted to the stage of specialized care after CT with intensive care. This is due to the fact that a priori gunshot wounds should be considered infected, and the period of clinical well-being in such patients is short. The elimination of the increase in cerebral edema, hypertension and dislocation syndrome is a complex task of the neurosurgeon and anesthesiologist-resuscitator.

Particular attention is paid to training the resuscitator to interpret the data of CT of the brain and Doppler ultrasound of the brain vessels. A decision on the choice of treatment tactics depends directly on the understanding of the obtained data, and not only on the conclusion of CT and ultrasound specialists.

If a deformity of the ambient cistern is detected, osmotherapy is performed, preferably using hypertonic sodium chloride solution, by jetting it into the central vein. The target value of sodium in blood plasma is 150 mmol/l. Infusions of up to 200 ml are given daily until CT normalization. The course of treatment is monitored 2-3 times a day with determination of blood and urine sodium concentration and osmolality [9, 10, 11].

Mannitol administration is possible in the absence of central venous access. The drug causes osmotic diuresis, which in case of cerebral edema is difficult to correct safely. Desmopressin should be administered in the presence of criteria of non-sugar diabetes, with a differential diagnosis of IADHSS (inadequate ADH secretion syndrome) and CSLS (central salt-loss syndrome) [10, 11, 13].

Some issues of intensive therapy of neurotrauma remain debatable: prolonged sedation, antibiotic therapy, acute symptomatic epileptic seizures, intestinal failure syndrome.

In our opinion, sedation in neuroresuscitation is a therapeutic measure aimed at controlling IP by reducing the need of the brain for oxygen and energy, reducing the pathological activity of the damaged brain. Sedation allows control of tachypnea, arterial hypertension, tachycardia in combination with analgesia, β-blockers and drugs of other groups. Prolonged sedation is performed by a combination of drugs with short-acting effects. Maximum doses of propofol together with maximum doses of dexdor may be ineffective, in which case midazolam and morphine are used. The duration of sedation sometimes reaches a month or more. However, if approached in a formal manner, a short-term sedation discontinuation to assess the level of consciousness allows a new sedation time countdown to begin, yet it is not a solution to the problem. Nevertheless, we have not observed a single case of "propofol infusion syndrome".

Decompression is almost the first line of treatment when a wounded person is admitted to the stage of specialized care after CT with intensive care. This is due to the fact that a priori gunshot wounds should be considered infected, and the period of clinical well-being in such patients is short. The elimination of the increase in cerebral edema, hypertension and dislocation syndrome is a complex task of the neurosurgeon and anesthesiologist-resuscitator

We studied the relationship between sedation and the patient's energy requirements by indirect calorimetry in wounded patients with brain injury, of whom 43% had an isolated cranial and brain wound, and 57% had a combined wound. We found a significant difference in energy requirement, loss, and nitrogen balance in the two groups of wounded (Table 3).

The indirect calorimetry in a wounded person in sedation has an average daily energy requirement of ±2500 kcal/day, and when sedation is disabled, it reaches ±3500 kcal/day. The data obtained suggest that the injury of

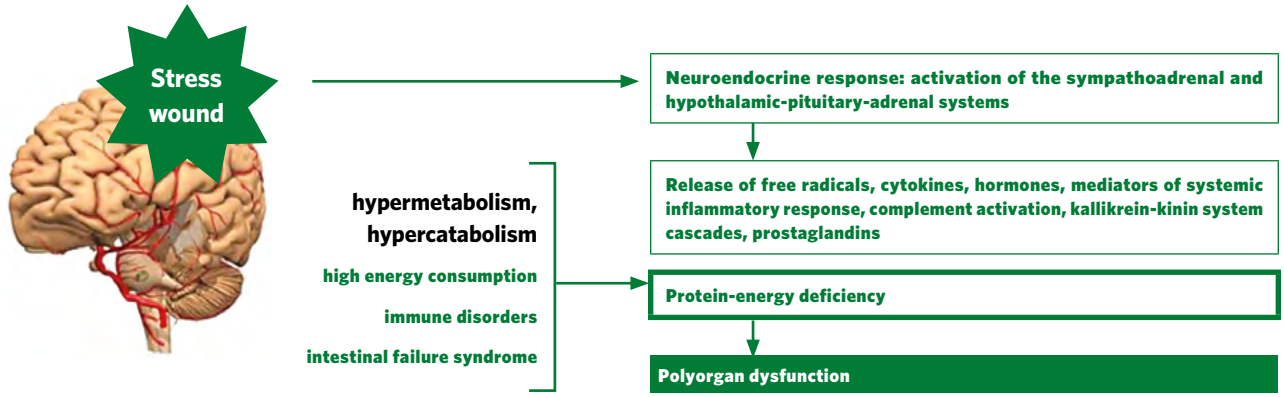

Fig. 3. Effect of cranial and brain wounds on the cascade of pathological processes

the brain triggers a cascade of neuroendocrine reactions: activation of the sympatho-adrenal and hypothalamic-pituitary-adrenal systems, which in turn leads to the release of free radicals, cytokines, hormones, mediators of systemic inflammatory response, activation of complement components, cascades of kallikrein-kinin system, prostaglandins. The result of these reactions is domination of the processes of hypermetabolism and hypercatabolism, energy expenditure increases, immune status is impaired, intestinal failure syndrome appears (Fig. 3).

The outcome of these events is protein-energy deficiency and multiple organ dysfunction (Fig. 4) [11, 13–15]. The nutritional support strategy developed in the hospital includes the following components in the daily volume of enteral, parenteral or mixed nutrition: energy value — 25–30 kcal/kg/24 h (indirect calorimetry determination of real energy requirements is desirable), proteins — 1.5–2.0 g/kg/day, carbohydrates — up to 6.0 g/kg/day, lipids — 1.0–1.5 g/kg/day, electrolytes, glutamine (G) — 0.3–0.6 g/kg/day, vitamins and micronutrients — daily set [14]. It is worth noting that with preserved function of the gastrointestinal tract, the entire volume of nutrition and fluid should be administered enterally.

Thus, the body's digestive system will be used as intended, and the intravenous administration of fluid volume is limited to the necessary intravenous forms of medication.

Concerning the issue of acute symptomatic epileptic seizures (ASES), it is necessary to outline the predictors of their occurrence: level of consciousness of 10 scores or less, depressed skull fractures, penetrating head trauma, subdural, epidural, intracerebral hematomas, convexital contusion foci, presence of injuring fragments. According to the literature, after severe gunshot wounds (penetrating wounds) of the skull and the brain, the risk of ASES reaches 30–50%. These data correlate with our observations: such patients account for 31% of the total number of wounded patients treated in the department. Diagnostic and treatment tactics for ASES are as follows: electroencephalographic (EEG) monitoring as soon as possible after admission. Particular attention should be paid to non-convulsive epileptic activity. According to our data, such conditions occur in 3-8% of cases. On the one hand, the percentage is not high, yet undiagnosed ASES is the reason for the lack of expected consciousness in a wounded person upon awakening and correlates with high lethality.

If there are predictors of ASES, we prescribe prophylactic treatment — carbamazepine. And in case of convulsions, they are treated: relenium 0.15–0.4 mg/kg bolus injection (or midazolam), valproic acid 6–7 mg/kg with subsequent infusion of 1 mg/kg/hr under EEG control, in the absence of results — deep sedation up to the use of general anesthetics, narcotic analgesics.

According to our data, CNS infectious complications in gunshot wounds occurred in 12.3% of the wounded, and in gunshot blast wounds — in 73%. Antibacterial therapy of CNS gunshot wounds is of particular interest due primarily to the blood-brain barrier (BBB), which creates an obstacle to achieving therapeutic concentrations of antibacterial drugs in the spinal fluid, with the difficulty of microbiological diagnosis and primary infection of wounds.

All patients who were admitted to the specialized care stage, according to the transfer epicrisis, received antibiotic therapy with 3rd generation cephalosporins and Metrogil [8, 16]. The main pathogen that primarily causes meningoencephalitis is gram-positive flora. Besides, it is necessary to prevent anaerobic infection taking into account the circumstances of the wound. The peculiarities of evacuation make certain adjustments in the continuity of therapy and may be the reasons for its ineffectiveness. As far as this scheme of antibiotic therapy is effective, we can judge from the following data: only in 21.4% of cases we did not have to escalate antibiotic therapy, taking into account the course of the infectious complication.

From our experience, in the absence of other

sources of infection, such as pneumonia, trauma of soft tissues, bones, abdomen, manifestations of meningoencephalitis occur on the 3-5th day, that is, exactly at the stage of AAE or already in the intensive care unit of the hospital. They include increase in leukocytosis, febrile temperature, cytosis with predominance of neutrophils and high protein level in the liquor. In this regard, after taking cerebrospinal fluid for microbiological examination and evaluation of renal function, we added vancomycin in a standard dose to antibiotic therapy. When vancomycin was administered, signs of meningoencephalitis regressed: leukocytosis decreased, temperature reaction normalized, cytosis decreased. On the basis of which it is possible to assume a Gram-positive infection of the CNS. At the same time, microbiological examination of the spinal fluid taken before vancomycin was prescribed did not obtain any flora.

In the case of bullet wounds, this scheme of antibiotic therapy was sufficient. Mine blast wounds have further stages of infection development, which is associated with their ballistic characteristics, multiplicity of wounding elements and fragments of skull bones, extensive foci of brain substance lesions [8, 13, 15, 16].

On the 7th-10th day in the case of blast-mine wounds the repeated increase of meningoencephalitis manifestations is caused by the addition of hospital flora also found in bronchial secretions, sinus contents, wound cultures. As a rule, it is Acinetobacter, less often — Klebsiella. In isolated cases, E. coli was obtained from the spinal fluid, with a marked increase in the spinal fluid cytosis up to 10000/3 and protein up to 16 g/l with 100% neutrophilia. In such a case, from the moment of admission to the intensive care unit we prescribe meropenem in the highest dose of 6 g per day and vancomycin in the standard dose. If renal function is impaired, linezolid is prescribed instead of vancomycin. If gram-negative flora is detected in the CSF, we cancel vancomycin and prescribe tigacycline at a higher dose in addition to meropenem. As a rule, this combination of antibacterial drugs allows to cope with meningoencephalitis, despite the multidrug resistance of the identified pathogens. In the absence of laboratory dynamics meropenem in this scheme is replaced by polymyxin at a dose of 2 mg/kg per day, which has always had a positive effect, even despite the low declared BBB permeability for tigacycline and polymyxin.

Treatment of the patients with gunshot wounds of the skull, brain and spinal cord, who survived combat trauma, surgery and evacuation to the rearward, requires coordinated interaction of specialists and application of complex treatment methods

Overcoming the resistance factors of Gram-negative flora is achieved by a combination of drugs. An important factor is high-quality surgical treatment and wound dressing, work with lumbar and ventricular drains in compliance with the rules of asepsis. In addition, in the treatment of meningoencephalitis we successfully used aminoglycosides in the presence of sensitivity of the identified flora, or in combination with meropenem and tigacycline in the absence of polymyxin. In almost 25% of cases there was a reaction to meropenem in the form of a rash like urticaria and an increase in transaminases by more than 3 times. In these cases, meropenem was replaced with cefepime/sulbactam. If an association of Gram-negative microorganisms (Acinetobacter, Klebsiella, Pseudomonas aeruginosa) was detected in the CSF, ceftazidime/avibactam was used. All antibacterial agents were used according to their pharmacokinetic characteristics.

Particular attention in antibiotic therapy is given to the nephrotoxicity of drugs due to the high frequency of contrast studies in the neurointensive care unit. The reciprocal deleterious effect of antibiotics and contrast agents on the development of acute renal damage should not be neglected.

Analysis of lethality allows us to conclude that the main causes of death were: vascular failure — sinus thrombosis, venous stasis, leading to cerebral edema and occlusion; liquor dynamics disorder due to destruction of structures and as a consequence of experienced ventriculitis, meningo-encephalitis; generalized infectious complications, sepsis.

Conclusion. Treatment of the patients with gunshot wounds of the skull, brain and spinal cord, who survived combat trauma, surgery and evacuation to the rearward, requires coordinated interaction of specialists and application of complex treatment methods. The task of physicians at all levels of care, especially evacuation, is to maintain continuity in the prevention of hypoxia and hypoperfusion. A wounded person with a severe gunshot wound of the brain is the most capacious patient, since

the regulation of the activity of all systems and organs is "broken" when the CNS is injured. Therefore, reducing the staging of neurosurgical care is the only way to reduce mortality. Delivery of the wounded person to the specialized stage of care, CT scanning, neurosurgeon's presence, and the earliest possible performance of DC, if indicated, are the components of success in the fight against intracranial hypertension and secondary complications. This approach makes it possible to reduce mortality and severe disability in a significant proportion of the injured.

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Significance of microvascular reconstruction in treatment of gunshot wounds of the face

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Abstract. Efficient Combat Casualty Care System aims at saving lives of the wounded as well as regaining their quality of life at the highest possible level. This article provides the data on using revascularized grafts to repair gunshot defects, presents data on the proportion, cause, severity and nature of facial wounds. We also give here recommendations on treatment modalities in these patients.
In between the 1 March and the 1 November 2022 in the Center of maxillofacial surgery and dentistry of Main Military Hospital named after N.N. Burdenko we performed 54 reconstructions, 47 of which were microvascular utilizing 49 free flaps.
Despite good vasculature in the face, it lacks soft tissues for closing vast gunshot defects. Damaged with high energy projectiles the tissue of the face gives poor bedding to the alloplastic implants, resulting in their exposure. Contemporary level of microvascular technique gives the plastic surgeon an efficient instrument for closing the gunshot defects in early wound healing period. We do not recommend using regional tissues to treat gunshot defects in the first place, because they are usually insufficient to fully resolve the defect, and at the same time it leads to a violation of the anatomy and even greater deformation of the soft tissues surrounding the defect. Titanium reconstructive and mesh plates are associated with high rate of exposure in the bone defects and are not to be recommended for the reconstruction either.

Keywords: gunshot wound, gunshot defect, defect closure, microsurgery.

Introduction. The problem of treatment of gunshot wounds appeared at the beginning of the era of firearms and remains relevant today. The process of improving the destructive properties of weapons does not stop for a moment, and the consequences of their use are increasingly difficult to manage. One of the reasons for this is the unpredictability of gunshot wounds. The ballistics of wounding firearms, including wound ballistics, are well studied, and at the same time the result of their influence on an organism varies greatly in severity and depends on many factors [1–3].

The pursuit of combat operations requires serious strain on each of the conflicting sides. This involves not only the use and loss of a large number of combat assets, but also collateral costs, such as the cost of providing aid to the wounded. We have not used the defining word "medical" because this aid is only a part of a complex of measures aimed not only at restoring the wounded person's health, but also at his further support after the injury that limits his ability to work and social activity.

In this regard, the effectiveness of medical care provided to the wounded implies the use of treatment methods aimed not only at preserving life, but also at restoring its quality to the highest possible level. This approach requires the competent administration of the flows of the wounded and the use of high-tech treatment methods.

In modern military conflicts, head and limb wounds are the most common. According to various data, facial wounds account for 8 to 26% of all combat wounds. Isolated facial wounds occur less frequently, of course. The appearance of a facial wounded person does not correlate with the severity of his or her condition. If free passage of air through the airways is ensured and the bleeding is stopped, such wounded people rarely develop life-threatening complications later on [4, 5]. However, without being fatal, facial wounds are accompanied not only by the loss of several important functions (speech, chewing, swallowing, etc.), but also by disfigurement, and can be a serious challenge for a surgeon, requiring high qualification and skills in the field of plastic surgery. This article analyzes the outcomes of patients with facial wounds. Data on the proportion, cause, severity, and nature of facial wounds are presented. Our experience in the treatment of such wounded patients is summarized and recommendations for the improvement of their medical care are given.

Materials and methods. All wounded patients treated in the maxillofacial and plastic surgery departments of the Center of Maxillofacial Surgery and Dentistry of the Main Military Hospital (MMCH) named after N.N. Burdenko were male, mean age was 31±1 years. All had isolated and combined wounds to the face, which determined at the time of admission the severity of their condition and the need for treatment by a maxillofacial/plastic surgeon. The majority (88%) of the wounds were fragmentation wounds. No correlation was observed between the type of wounding projectile and wound severity. The majority (95%) of cases of wounds were admitted from Level 1 and Level 3 hospitals. The remaining 5% were treated at Level 4 and Level 5 hospitals in the previous phase. All patients underwent 138 surgeries in the hospital. All surgeries were divided into three groups according to the surgeon's qualifications and the operating room's material and technical equipment: surgical wound management, osteosynthesis of the facial skeleton, and reconstructive plastic surgery (Fig. 1). Surgical treatment (debridement) (ST) of wounds included operations consisting in the removal of foreign bodies, nonviable tissues, with elements of local tissue plastics. If osteosynthesis was required in addition to the above-mentioned actions, the surgery was included in the second group.

The same principle was applied for the third group — reconstructive-plastic surgeries. This group of operations consisted of elimination of gunshot defects using mainly microsurgical techniques. Operations in this group were the most complicated and required a high level of competence in this area not only from the surgeon, but also from the entire surgical staff, and availability of appropriate operating room equipment. Reconstructive-restorative surgeries accounted for more than 40%. They were performed in 49% of cases as primary operations, i.e., when no attempts were made at the previous stages

42%	Reconstructive-restorative
47%	Osteosynthesis of facial skeleton bones
11%	Surgical treatment of wounds

Fig. 1. Division of patients into groups according to the type of operations

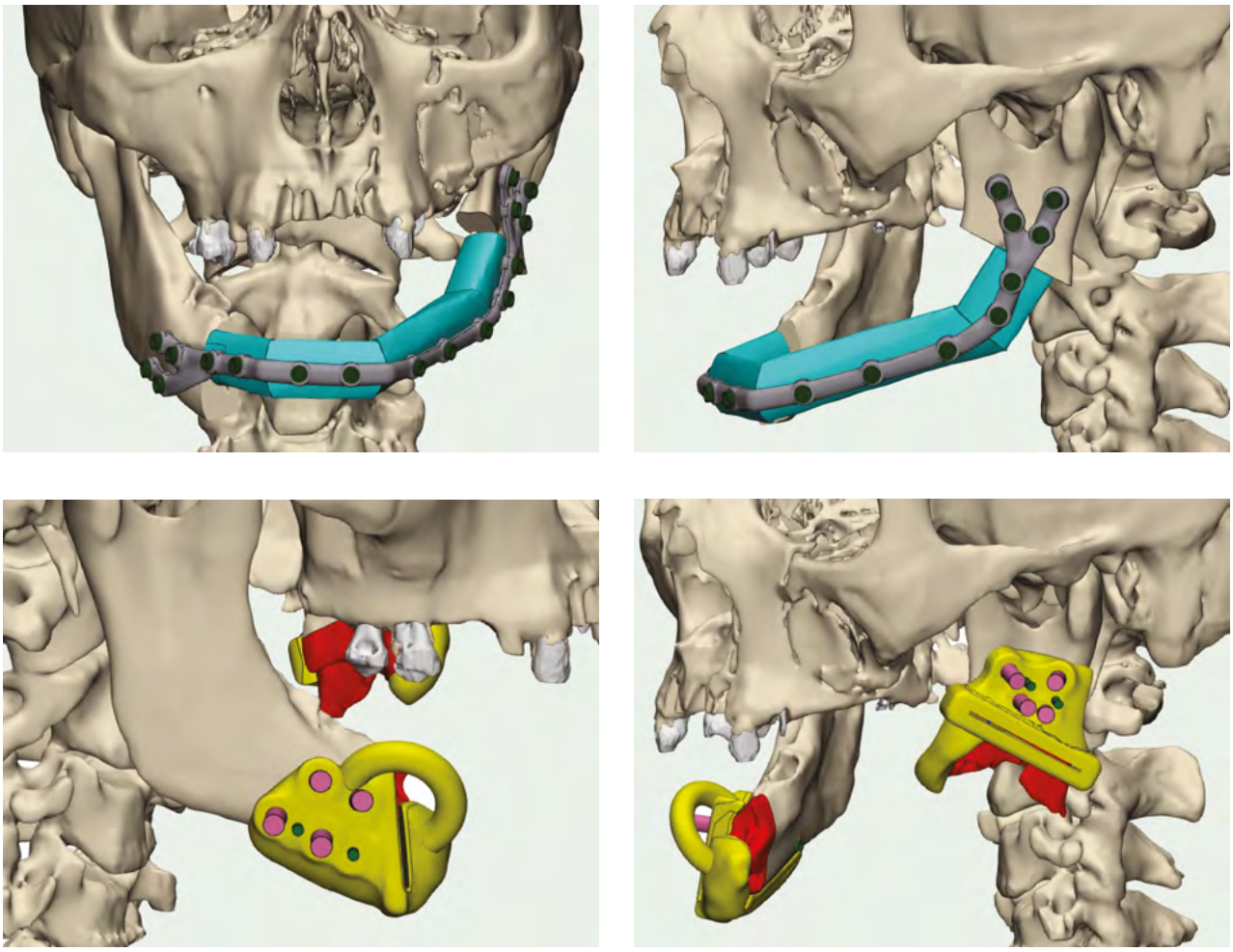

Fig. 2. Based on the planning results, surgical templates and individual fixation plates made of titanium were fabricated

to eliminate the gunshot defect. Secondary surgeries were considered to be operations in wounded patients who had already undergone attempts to replace the defect of bones or soft tissues of the facial skeleton at previous stages — osteosynthesis, plastic surgery with local or regional tissues — but the proper effect was not achieved.

Primary operations were planned and performed according to the following algorithm. On admission, a maxillofacial surgeon evaluated the patient's injury. A multispiral computed tomography (MSCT) scan of the facial skeleton bones was performed with a step of no more than 1.125 mm. If the surgeon was experienced enough to determine the defect of the facial skeleton bones and thus the need for reconstructive-reconstructive surgery, an MSCT of the prospective donor area was performed with the same spacing. The obtained data were emailed to bioengineers for segmentation of the computed tomography (CT) data and preparation of 3D virtual models of the facial skeleton bones and the donor area, followed by planning, which could usually be done the next day. Based on the planning results, surgical templates and individual fixation plates made of titanium were fabricated (Fig. 2), and

Table 1. Grafts used to repair facial gunshot defects

Grafts used	Number
The fibula	24
Outer anterior surface of the thigh	10
Crest of the iliac bone	10
Radial	3
Radial bone	1
Medial Sural Perforating	1
Total	49

Table 2. Incidence of facial defects by zones and structures

The structure involved in the defect	Number of wounded	Percent
Lower jaw	25	54,3%
Upper Jaw	7	15,2%
Middle zone	9	19,5%
Cranial vault	5	11,0%

reconstructive-reconstructive surgery was performed.

If there was no need to use revascularized bone grafts, ST of wounds prior to their cleansing and repair of the defect with revascularized dermal-facial or dermal-facial-muscular grafts were performed.

Results. During the above-mentioned period 54 reconstructive-restorative surgeries were performed in the Center of Maxillofacial Surgery and Dentistry: 47 operations using 49 revascularized grafts (Table 1).

Revascularized transplants engraftment occurred in 94% of cases, partial necrosis of the graft was observed in two (3%) patients, and in another two (3%) patients the graft died completely, which required repeated surgery with its replacement. The average duration of microsurgery was 333±15 minutes. The average duration of graft ischemia was 42 minutes.

23 (49%) reconstructive-restorative surgeries were performed primary and 24 were performed secondary. In the group of secondary reconstructive-restorative surgeries, in 11 cases the wounded had undergone osteosynthesis of the facial skeleton bones for multiple comminuted gunshot fractures at previous stages. As a result, osteomyelitis developed in the fixed bone fragments with the formation of a bone defect, which required reconstructive surgery. In 9 cases, the bone defect had already been diagnosed at previous stages.

Titanium constructions were used to eliminate it: reconstructive and mesh plates. The latter erupted in the postoperative period, which required their removal and elimination of the defect with revascularized bone grafts. Another five wounded patients with gunshot defects underwent unsuccessful plastic surgeries using local or regional tissues. The time from wounding to primary reconstructive surgery was 22±3 days, whereas the time from wounding to reconstructive surgery in group 2 was 117±12 days. The postoperative hospitalization time for patients in the first and second groups was 17±2 days and 17±1 days, respectively. The incidence of defects by anatomical zones is presented in Table 2

Discussion. According to different sources, maxillofacial wounds account for 8 to 26% of wounds on the battlefield [6, 7]. Despite their frightening appearance, they rarely result in traumatic shock, and the main danger to the wounded person's life is in the disturbance of airway passages and bleeding [8]. Tracheostomy and tamponade of the face and neck wounds eliminate these risks in the vast majority of cases. Stabilization of mandibular fragments with an external fixation apparatus can reduce the pain caused by moving bone fragments and prepare the wounded person for evacuation.

Despite the relatively small percentage of facial wounds compared to limb wounds, amounting to 54–70% [9, 10], according to our data, more than 40% of the first cases require reconstructive-reconstructive surgery. The fact that even small defects in the face have an extremely negative impact on patients' quality of life is extremely important [11] compared to similar defects in the extremities [12].

Even with a favorable course of the wound process in the facial area, there are no "extra" tissues in this zone that could be moved to eliminate extensive soft tissue defects. This fact significantly complicates the task of elimination of defects of the facial skeleton bones. Successful use of non-blood supplied bone fragments requires the presence of well- blood supplied soft tissues around them as well as the absence of infection. A comparison

of non-blood supplied and blood supplied bone grafts in reconstructive mandibular surgery performed by R.D. Foster et al. showed engraftment in 69% of cases of non-blood supplied grafts and in 96% of cases of blood supplied grafts [13]. The use of artificial materials to repair bone defects, as well as in the case of non-blood supplied bone, requires ideal conditions with regard to the surrounding soft tissues, which in the case of gunshot wounds cannot be a priori. The complication rate for reconstructive mandibular surgery using only a reconstructive plate ranges from 34% in the first 6 months after surgery to 64% within the first year [14, 15], and this does not only apply in the early period after wounding. In the later stages, scars are formed in the wound area, which themselves are not those ideal, well-blooded tissues necessary for the integration of non-blood supplied bone and alloplastic materials.

Our experience revealed a low level of proficiency in methods of plastic elimination of facial defects by surgeons even in Level 5 hospitals. Underestimation of the extent of injuries and lack of skill in reconstructive-restorative techniques led to the performance of unnecessary operations, unjustified waste of consumables, increased duration of the wounded person's stay in the hospital and his rehabilitation period. According to our data, on average, 117 days passed from the moment of wounding to reconstructive-restoration surgery in these patients. This means that after all this time the patient actually "arrived" at the original reference point - the moment of wounding. In addition to this, scar tissue deformation that occurred within the specified period significantly complicates the performance of plastic surgery and reduces its effectiveness.

Improvements in microsurgical techniques have made the use of revascularized grafts an effective way to eliminate defects of any localization. Depending on the localization, the complication rate when using revascularized grafts to repair defects is 9.6% in the head and neck, 5.6% in the extremities, 4.9% in the breast, and 2.5% in the abdomen [16]. Reconstructive microsurgery is most popular in oncology. Being taken from donor areas and having their own source of blood supply, these grafts favorably influence blood supply of the changed tissues in the recipient area. The use of revascularized grafts to repair gunshot defects within the first 3 weeks after wounding allowed to eliminate the defect immediately in more than 95% of cases and send such a patient to rehabilitation within 17 days on average.

Thus, revascularized grafts are an ideal plastic material for repairing defects in compromised tissue conditions, such as gunshot wounds.

Conclusion. Evaluating our experience in the use of revascularized grafts for elimination of gunshot defects in the head area we can state with confidence their high efficiency even in the early period after the wound. Attempts to use titanium constructions and non-vascularized bone grafts for this purpose in the vast majority of cases lead to failure and necessity of repeated reconstructive surgeries. We do not recommend using regional tissues to repair gunshot defects in the first place because they are usually insufficient to fully eliminate the defect, and at the same time it leads to violation of anatomy and even greater deformation of the soft tissues surrounding the defect.

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Treatment of a combined gunshot wound with a defect of the humerus and radial nerve (clinical observation)

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Abstract. Treatment of patients with gunshot bone and soft tissue defects of the extremities requires non-standard approaches and the participation of doctors of various specialties. The application of additive and microsurgical technologies allows one-stage restoration of bone defects and functionally important soft tissue formations.
Objective: To demonstrate the possibilities of modern reconstructive-plastic surgery in combination with additive 3D-technology in the treatment of patients with severe gunshot wounds of the extremities.
Clinical case: a patient with a combined wound of the chest and upper limb with a primary defect of the humerus and radial nerve. Treatment was based on damage control surgery (DCS) and damage control orthopedic (DCO) tactics. X-ray, computed tomography, and angiography were used for diagnostics and preoperative planning. Based on the CT data, a 3D model of the autograft, resection templates, and a metal structure for osteosynthesis were made. After stabilization of the general condition of the wounded man and elimination of the risk of infectious complications, a one-stage replacement of the radial nerve defect at the level of the middle third of the shoulder with a gastrocnemius nerve autograft was performed; the upper and middle third humeral bone defect was replaced with a free blood-supplied fibula autograft with osteosynthesis using an individual 3D plate with bacteriostatic hydroxyapatite spraying in combination with zinc.
A positive anatomical and functional outcome was achieved in the treatment of a patient with a gunshot defect of the humerus and radial nerve.
An individual complex approach combined with innovative technologies makes it possible to achieve good anatomical and functional results in the treatment of patients with primary combined limb gunshot defects.

Keywords: gunshot wounds, bone defect, nerve defect, 3D technologies, defect replacement.

Introduction. Generalization of the experience of the world wars and local armed conflicts provides convincing evidence that over 60% of the wounded have injuries of the musculoskeletal system, which in 90% of cases require specialized surgical treatment [6]. Stable early fixation of open and gunshot fractures of long limb bones during medical care reduces the mortality rate and the number of complications among the injured with severe combined trauma [7]. At the stage of specialized medical care, the choice of the method of final osteosynthesis of

A

B

Fig. 1. Radiographs of the left upper extremity on admission to the hospital

the fracture should be determined [1, 4]. The decision on surgical treatment of gunshot combined shoulder defects, which are "critical" in terms of the probability of the development of gunshot osteomyelitis, nonunion, arthropathy, and neuropathy with marked impairment of upper limb function, remains an urgent problem of modern traumatology and orthopedics [1].

Improvement of weaponry leads to changes in the nature of combat injuries of the limbs. The development of modern technologies in the broadest sense predetermines

A

B

Fig. 2. Appearance of gunshot wounds of the patient

the revision of approaches and expansion of treatment possibilities for the wounded with gunshot limb defects [2, 4]. The history of 3D-printing is about 40 years old. However, in traumatology and orthopedics this technology has been applied in the last decade. The fundamental stage of 3D technology is the design and creation of an individual graft based on CT data, which corresponds in shape and size to the bone defect [3, 9, 10]. Due to their individuality, anatomicity and durability, 3D grafts open up new perspectives and opportunities in solving the problem of bone defect replacement.

The restoration of the anatomy of a destroyed long bone throughout, especially in young individuals with high functional demands, appears to be an extremely difficult task. A favorable outcome of treatment ensures a high quality of patient's life, return to a habitual way of life, and eventually restoration of the fight ability. The peculiarities of a gunshot wound often do not allow the use of implants for internal osteosynthesis in the treatment of extensive bone defects, and preference is given to long-term treatment in the Ilizarov external fixation apparatus (EFA) [5].

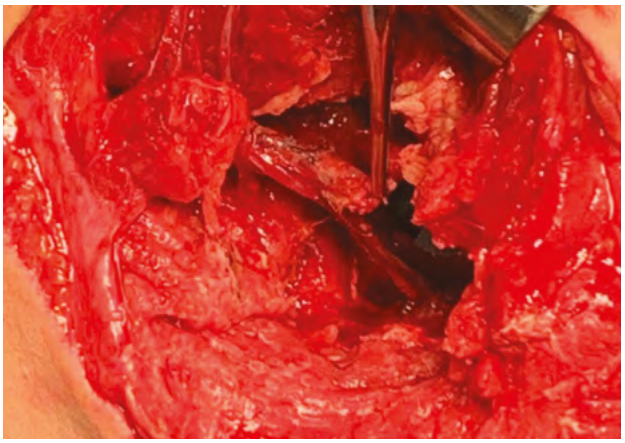


Fig. 3. Appearance of the injured radial nerve

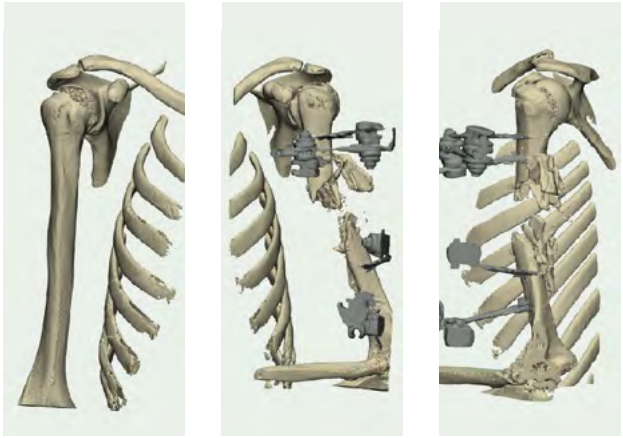


Fig. 4. 3D picture of healthy and injured humerus

Fig. 5. 3D model of an individual bone plate

Objective. To show the possibilities of modern reconstructive-plastic surgery in combination with additive 3D-technologies for treatment of patients with severe limb gunshot wounds.

Material and methods. Clinical case. Patient G., 35 years old. Diagnosis: combined gunshot wound of the chest and extremities, fragmentary blind non-penetrating wound of the left half of the chest, fragmentary penetrating wound of the left shoulder in the upper and middle thirds with primary defect of the humerus and radial nerve injury, moderate grade posthemorrhagic anemia, grade II traumatic shock. Humerus fracture according to Gustillo-Andersen classification 3C, according to the Main Military Clinical Hospital (MMCH) named after academician N.N. Burdenko classification of gunshot fractures — OS-1.2C3 IIIb CH1. First aid was performed at the place of injury, and then the patient was transported by ambulance to the stage of qualified medical care, where primary surgical treatment of the wounds of the left chest (with removal of metal fragment) and the left upper extremity with fixation of the fracture with apparatus from the military-type rod kit (MTRK) was performed. Within the first 24 hours the wounded was delivered by air medical service to the MMCH named after academician N.N. Burdenko.

The patient was admitted to the Center of Traumatology and Orthopedics (CTO), where on admission he underwent standard left humerus X-rays in two projections, revealing a 65-mm primary humerus gunshot defect (Fig. 1). Due to the presence of signs of left radial nerve neuropathy, an electroneuromyography (ENMG) of the left upper extremity was performed, which revealed a complete absence of conduction in the zone of innervation of n. radialis.

On the first day after admission to the CTO, the patient underwent reassembly of the apparatus from the MTRK and thereafter, staged surgical treatments using the negative pressure wound care system were performed every 72 hours (Fig. 2).

During surgical treatment, examination of the radial nerve was performed, which revealed its damage with a primary defect of more than 60 mm (Fig. 3).

Then a CT angiography of the injured segment and the contralateral limb was performed as part of preoperative planning, after which a three-dimensional model of the left humerus diaphysis defect was created in close collaboration with "Endoprint" engineers based on the CT data in the 3D-printing laboratory (Fig. 4).

On the basis of the obtained 3D model, the area of the primary humerus defect and subsequently the size of the donor bone autograft for its replacement were determined. Next, the zones of recommended sawing of

Fig. 6. Bone autograft harvesting stage of the fibula according to the preliminary template

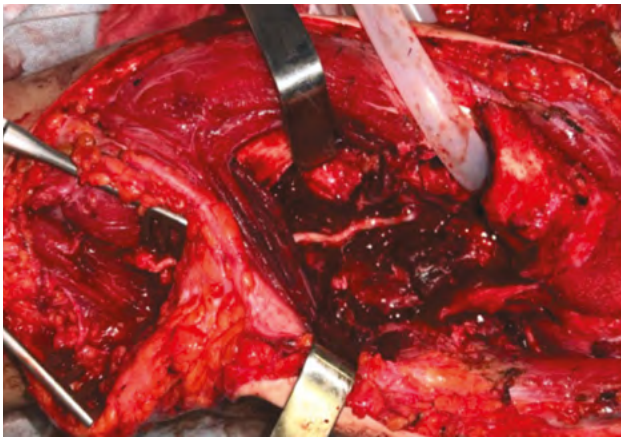


Fig. 7. Replacement of the defect of n. radialis with an insert from n. suralis

humerus bone fragments for free autograft placement were identified and templates were formed to facilitate intraoperative sawing.

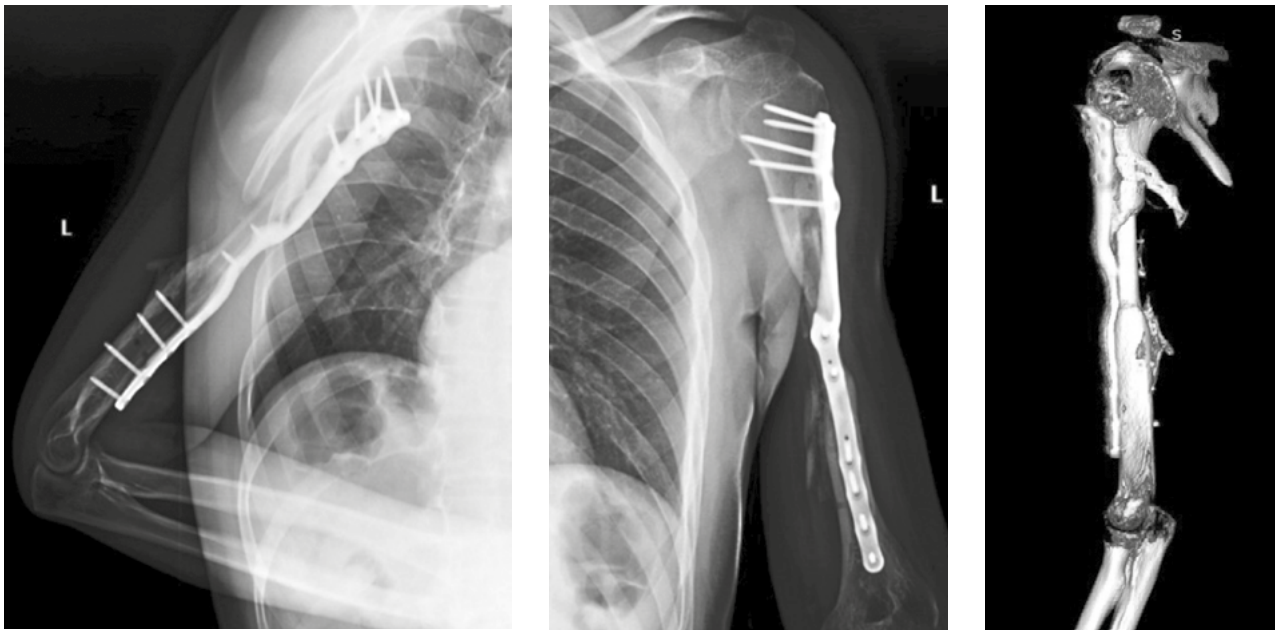
The next stage of 3D modeling was the design of an individual bone plate for osteosynthesis of the left humerus. The implant was modeled to exclude compression of the metal structure and the feeding vessels of the donor bone autograft (Fig. 5).

Due to the presence of a gunshot fracture with a primary extended bone defect of the left humerus, a radial nerve defect, and a large volume of planned surgical treatment, the decision was made to apply bacteriostatic

A

B

Fig. 8. Osteosynthesis of the left humerus with a 3D plate: A — external view; B — postoperative radiographs



A B

Fig. 9. Radiographs (A) and CT scan (B) 4 months after surgery

Fig. 10. Functional result

spraying on an individual bone plate, namely hydroxyapatite (HAP) and zinc (Zn), previously known to have antibacterial and bacteriostatic properties in order to prevent infection complications [8].

43 days after the injury the victim underwent a one-stage surgical operation: replacement of the defect of the left radial nerve at the level of the middle third of the shoulder with an autograft from the calf nerve of the left shin and replacement of the gunshot defect of the middle third of the left humerus with a free blood-supplied autograft from the left fibula with osteosynthesis with an individual 3D-bone plate with bacteriostatic HAP spraying in combination with Zn (HAP+Zn).

At the first stage, a donor bone autograft was taken from the fibula. The size of the graft and its sawing were performed according to previously prepared 3D templates (Fig. 6).

Intraoperatively, during examination, the radial nerve was detected, its nonviable areas were dissected, resulting in visualization of the nerve defect with a length of more than 100 mm. Then, the calf nerve was harvested, followed by the latter placed in the position of the radial nerve defect, neurorrhaphy was performed between the ends of n. suralis and the proximal and distal ends of n. radialis (Fig. 7).

The next step was to place the peroneal flap in the position of the left humerus diaphysis defect and to perform osteosynthesis of the left humerus with an individual plate with bacteriostatic HAP+Zn spraying (Fig. 8).

Results and discussion. The postoperative period demonstrated no specific conditions; the wounds healed with primary tension. Six weeks after surgery, the patient underwent rehabilitation-restorative treatment aimed at developing joint movements in the left upper extremity. Four months after surgery, control radiographs and CT scans revealed signs of bone autograft remodeling (Fig. 9).

Upper extremity function was evaluated using the DASH and Constant Shoulder Score questionnaires. The findings indicated satisfactory functional results of the limb (DASH — 32 scores and Constant Shoulder Score — 81 scores) (Fig. 10).

Conclusions. One of the main problems in the treatment of the wounded and injured with extensive bone and soft tissue defects of the limbs faced by the operating surgeons is the choice of the optimal treatment tactics.

The issue of tactics selection is primarily related to the nature and features of the gunshot wound, accompanying anatomical and physiological disorders in the form of local blood circulation insufficiency, deformities, pronounced anatomical segment shortening and neurological deficit.

The development of innovative technologies has opened up new opportunities for an individualized approach to the treatment of this category of patients.

This case demonstrates an unconventional approach combined with high quality standards of care that include innovative technology, appropriate equipment, and professionalism of the surgical team.

All of the above in combination with high patient motivation made it possible to achieve a satisfactory anatomical and functional result as soon as possible after the injury.

The issue of tactics selection is primarily related to the nature and features of the gunshot wound, accompanying anatomical and physiological disorders in the form of local blood circulation insufficiency, deformities, pronounced anatomical segment shortening and neurological deficit. The development of innovative technologies has opened up new opportunities for an individualized approach to the treatment of this category of patients

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Treatment of blind shrapnel wound with injury of the liver, left lung, diaphragm, and heart, complicated by intracardiac thrombosis and material embolism of the left common femoral artery

UDK 616-001

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Abstract. The experience of staged treatment of a wounded man with a thoracoabdominal shrapnel wound, accompanied by the development of complications not typical for combat trauma: intracardiac thrombosis in the location of the interventricular septum shrapnel wound and material embolism of the left common femoral artery with a foreign body (shrapnel) from the left ventricular cavity is presented.

Keywords: cardiovascular surgery, thrombosis, foreign body, material embolism.

Introduction. The distinctive feature of the modern armed conflict is the prevalence of combined blast and fragmentation wounds over bullet wounds. The peculiarities of a wounding projectile and its ballistic characteristic assume appearance of a great number of the wounded with complex damages of several anatomic regions, prevalence of blind wounds with tortuous wound channel, penetration of foreign bodies into lumen of hollow organs and even blood vessels. Full-fledged medical care for this group of wounded can be provided only in the conditions of specialized medical institution with the possibility of using high-technology methods of treatment.

Clinical case. A patient S., born in 2003, was delivered to the hospital by air ambulance on the 5th day after a shrapnel wound received in the line of duty. Drainage of the left pleural cavity was performed at the stage of first aid. On the same day he was transferred to a temporary hospital. The examination revealed hemoperitoneum, drained hemopneumothorax on the left side, cardiac wound (fragment size 1.5×2 mm), no data on hemopericardium and cardiac tamponade were obtained. The following surgery was performed: laparotomy, suturing of the left diaphragmatic dome, coagulation of the wound of the left lobe of the liver, drainage of the abdominal cavity. On the 2nd day after the wound, he was transferred to the district hospital and after stabilization of his general condition he was delivered to the Main Military Clinical Hospital (MMCH) named after academician N.N. Burdenko. On admission he complained of pain and numbness in the left lower extremity, slight pain along the suture of the anterior abdominal wall and in the area where the drainage of the left pleural cavity was located.

X-ray examination in the MMCH revealed a foreign body in the projection of the heart.

Echocardiography (EchoCG) was performed, which showed a hyperechogenic foreign body about 3×4 mm in

size, moving along the wall — most likely, a fixed metal fragment in the projection of basal segments at the border of the left ventricular (LV) anterior wall and the anterior part of the interventricular septum. An area of the wall with an altered echographic structure — an intramural hematoma — is observed in the area of the fixed fragment. An additional movable isoechogenic structure sized 22×5 mm, most likely a thrombus, departed from this area and visualized in the LV cavity. Several false chords are also visualized in the LV cavity, one of which is torn off and mobile in the LV cavity. The pericardial cavity contains no more than 100 ml of free fluid (Fig. 1). Given the complaints of pain and numbness in the left lower extremity, we performed ultrasound Doppler ultrasonography of the lower extremity vessels. An intraluminal hyperechogenic mass 15 mm long was visualized in the bifurcation of the left common femoral artery and in the mouth of the left superficial femoral artery, which gave an acoustic shadow obstructing the blood flow, equivalent to 75% stenosis of the vessel lumen.

Considering the presence of intracardiac flotation thrombus as well as a foreign body in the left common femoral artery with blood flow disturbance equivalent to 75% stenosis, the patient was identified as an indicative for urgent surgical treatment of the left common femoral artery and heart. The angiosurgical and cardiosurgical teams started simultaneously.

The first stage was revision of the left common femoral artery. There was no damage to soft tissues and muscles. Prior to the origin of the left superficial femoral artery, local thickening of the common femoral artery was noted. A dense foreign body was palpated in the lumen of the vessel. The common femoral artery was clamped, opened, and an irregularly shaped metal fragment with sharp edges measuring 20×15 mm was extracted from the lumen. Blood flow through the femoral artery was restored, and the femoral artery was sutured with a twist suture (Fig. 2).

A median sternotomy was performed in the second stage. There was a small amount of serous hemorrhagic fluid in the pericardium. A lysed hematoma was detected along the posterior wall of the LV. Cardiopulmonary bypass was connected; pharmaco-cold cardiac arrest was performed. After removal of the hematoma, on the surface of the diaphragm and LV posterior wall, oval penetrating defects with smooth contours of about 15 mm in diameter, which were filled with organized thrombotic masses, were revealed. The defects were sealed with sutures using teflon gaskets (Fig. 3).

The next stage was to open the aorta, the revision of the aortic valve revealed no damage to the latter, and in the upper third of the interventricular septum there was a wound area, to which an organized thrombus was fixed with dimensions of 25×5 mm, the flotation fragment

Fig. 1. Flotation thrombus and torn off false chord in the left ventricle

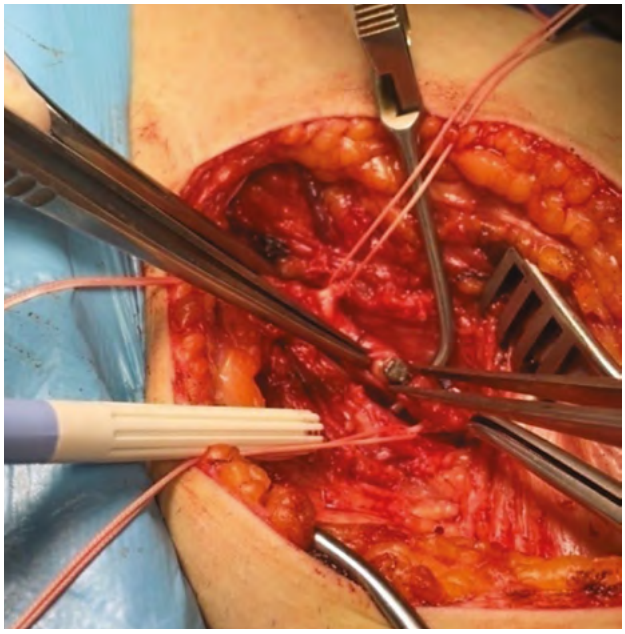

Fig. 2. Removal of a foreign body (metal fragment) from the left common femoral artery

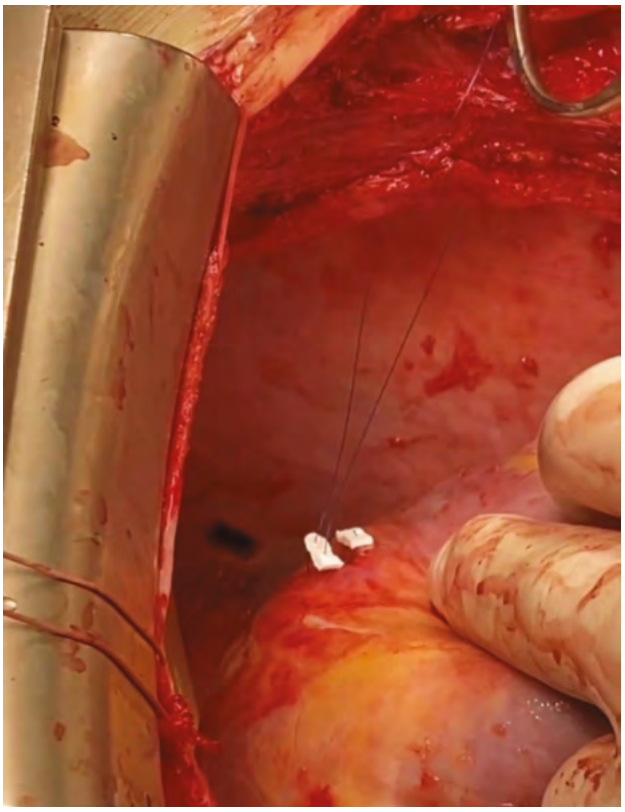

Fig. 3. Suturing of the wound defect of the posterior wall of the left ventricle of the heart. Wound canal in the diaphragm is visible

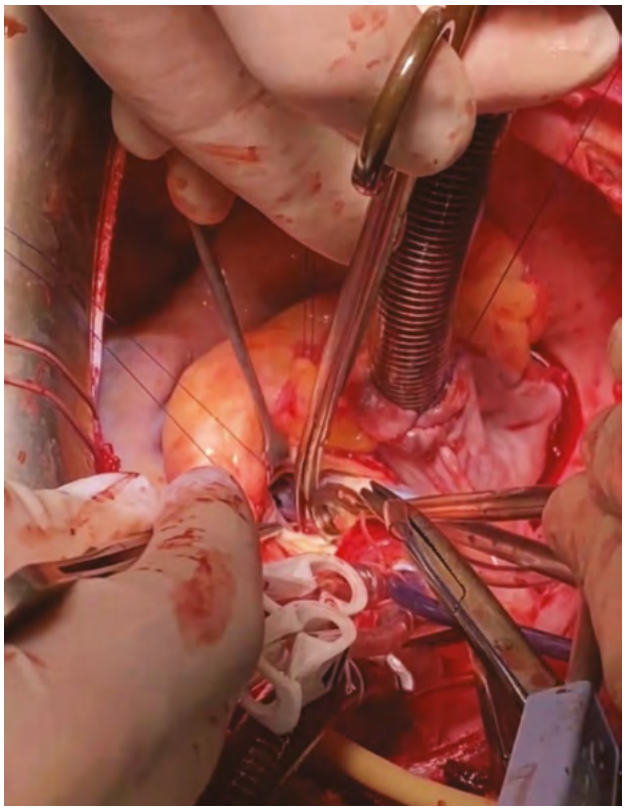

Fig. 4. Removal of thrombus from left ventricular cavity

was about 20 mm long. Fresh thrombotic masses were observed on the surface of the organized thrombus. A torn false chord was also found in the LV cavity. The thrombus from the lumen of the outflow tract and the false chord were removed (Fig. 4). Attempts to visualize and remove the fragment from the interventricular septum, considering its small size and deep location in the myocardium, could lead to damage of the aortic valve, increase of the wound surface, which is associated with the risk of repeated thrombosis in the wound area, and therefore it was regarded as not reasonable.

The patient was transferred to the ICU on the 2nd day after surgery. During further treatment there were repeated ultrasound Doppler studies of the lower limb vessels, EchoCG.

According to the results of ultrasound Doppler sonography (USDG) of the left femoral artery, the blood flow in the area of material embolism by a fragment did not change, no signs of vessel lumen narrowing and thrombosis were revealed. There were no clinical findings of left lower extremity ischemia. According to EchoCG findings, there was no evidence of thrombus in the surgical site and cardiac cavities, there was a fixed metal fragment of 3×4 mm in the basal myocardial thickness at the border between the anterior wall of the LV and the anterior part of the interventricular septum.

Conclusion. Thus, the presented clinical observation shows the possibility of complex combined wounds of various anatomical areas and organs when exposed to even one damaging agent. In this case one fragment damaged the liver, diaphragm, posterior wall of the LV, interventricular septum, leaving a fragment in it and causing life-threatening thrombosis, then it moved with the blood flow to the left common femoral artery, causing material embolism. Full treatment in this case is possible only in the conditions of a large specialized institution with the possibility of providing high-technology medical care.

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Features of providing specialized surgical care for gunshot wounds of the neck with damage to hollow organs (larynx, trachea, pharynx, esophagus)

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Abstract. The objective of this work is to share our experience in providing specialized surgical care to patients coming from stages of medical evacuation with wounds of hollow neck organs.
A special military operation (SMO) takes place in an environment different from previous local wars. The nature of military operations and the saturation of the enemy's armed forces with new types of weapons gave a significantly higher number of wounded than previous local conflicts. The predominance of mine-explosive shrapnel wounds, different time intervals from injury to getting to the stage of specialized medical care for wounded with already existing purulent complications of gunshot wounds are the features of the SMO. Wounded with injuries of the hollow organs of the neck, entering the MMCH named after N.N. Burdenko from 3 to 6 days after injury, with already developed purulent complications, require comprehensive intensive therapy and participation in the treatment of specialists of various surgical specialties.
An integrated approach with the compliance with the regulations of military-field surgery using new methods of diagnostics and treatment of wounds can improve the effectiveness of therapy and reduce the number of lethal outcomes. This article discusses diagnostic and treatment algorithms for different variants of neck wounds.
The experience of the described cases of successful treatment of wounded with injuries of the hollow organs of the neck shows the possibilities of MMCH named after N.N. Burdenko in treatment using various methods, and can be useful to doctors of both the Ministry of Defense and the Ministry of Health of the Russian Federation.

Keywords: gunshot wounds of the neck, wounds of the larynx, wounds of the trachea, wounds of the pharynx, wounds of the esophagus, vacuum aspiration therapy, pharyngostomy, esophagostomy, laryngotracheostomy, tracheostomy.

The tasks of the ENT department of the Main Military Clinical Hospital (MMCH) named after N.N. Burdenko is responsible for treating wounded people with injuries of ENT organs: nose, paranasal sinuses, pharynx, larynx, cervical trachea, esophagus, and ear.

In our opinion, special attention should be paid to the problems arising in the delivery of specialized surgical care to the wounded in the neck with hollow organ injuries (larynx, trachea, pharynx, esophagus), arriving in the MMCH from the frontline stages of medical care. This is due to the severity of such wounds associated with the risk of asphyxia development, as well as purulent complications due to infection of the wound from outside and from the cavity of the esophagus, when saliva and reflux gastric contents get into the wound.

Moreover, considering the difficulties and duration of evacuation from the broad area of combat operations, such patients are admitted to MMCH on the 3rd-6th day after the wound in the stage of purulent process development not only in the wound, but also in the surrounding tissues of the neck and thorax.

The peculiarity of such wounded is often a combined injury of other anatomical areas (head, limbs, chest, abdomen), which aggravates the course of the wound disease.

According to Zavrazhnov A.A. et al. (2021), the frequency of combat wounds to the neck ranges from 1 to 4%. This relatively low percentage of injuries is explained by the small surface area of the neck and its protected position. However, these types of wounds are always dangerous. The death shortly after a neck wound is caused by damage to large blood vessels and asphyxia due to acute stenosis of the airways. When the esophageal tracts of the neck are damaged, the patients rescued in the frontline stages of evacuation subsequently develop severe purulent complications (neck phlegmon, mediastinitis, sepsis, etc.). The number of gunshot wounds to the neck can increase several times when the enemy actively uses fragmentation ammunition.

All patients with gunshot wounds to the neck admitted to MMCH from the frontline stages of evacuation undergo a comprehensive diagnosis, irrespective of the volume of investigations in the previous stages. A computed tomography (CT) scan of the neck with contrast, with a slice spacing of no more than 1.25 mm, is performed to assess the spread of the inflammatory process and the relationship of foreign bodies to the main vessels of the neck. Fibro-esophagogastroscopy, fibroscopy of the larynx, trachea, and bronchi are necessarily performed to assess the condition of hollow organs and the presence of their perforations. In addition to general clinical investigations, the scope of laboratory diagnosis includes culture of wound discharge for microflora and sensitivity to antibiotics with detection of possible beta-lactomase- and carbopenemase-producing pathogens.

Depending on the nature and combination of injuries of hollow neck organs, the wounded admitted to MMCH with gunshot penetrating wounds of the neck, in our opinion, should be divided into four main groups:

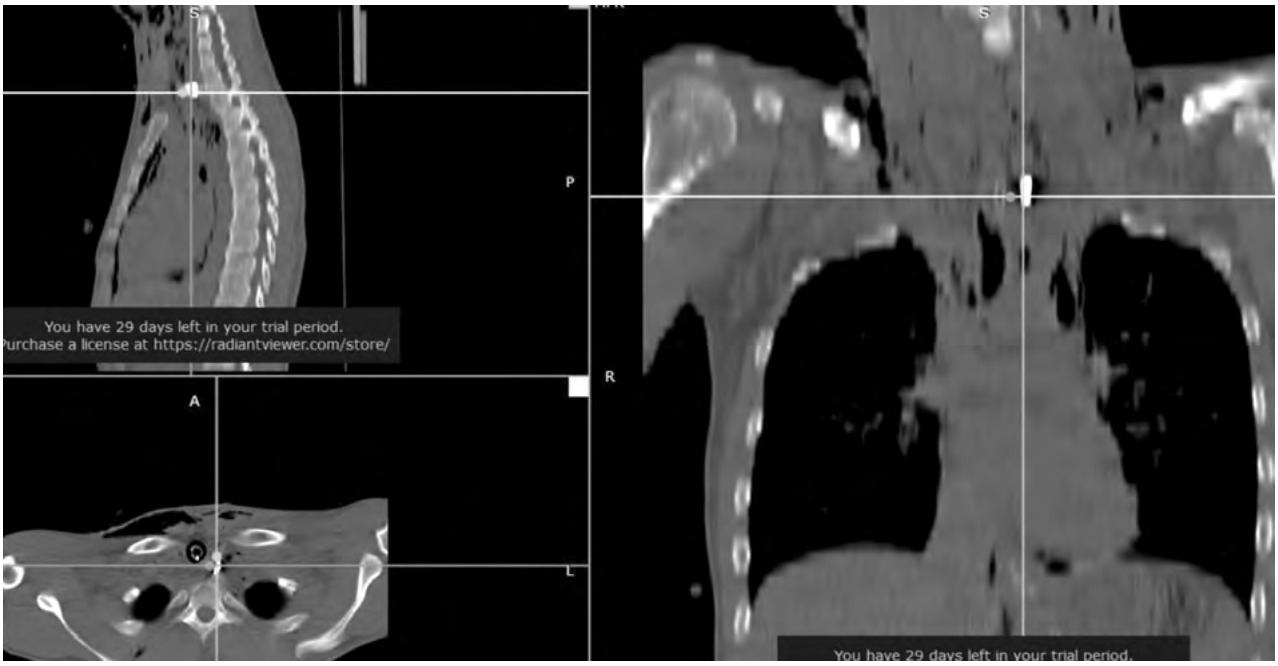
The first group — penetrating wounds of the cervical esophagus (without a complete rupture), wounds of the larynx and trachea. It should be noted that such wounds traditionally pose a great danger due to the spread of virulent purulent infection in the loose neck tissue with the development of phlegmon and mediastinitis. According to researches of academician V.A. Porkhanov, as early as 6 h after esophageal perforation purulent infiltration of all layers of the esophageal wall is observed. Therefore, treatment of such wounded, especially after a long evacuation, is very difficult.

In the setting of MMCH during complex treatment of the wounded with gunshot penetrating wound of the esophagus the scope of surgical treatment includes wide wound drainage, excision of nonviable tissues, cartilage fragments, suturing of esophageal defect with suture covering by transferred muscle-fascial flap on a feeding stem from omohyoid or sternocleidomastoid muscle, suturing of defects of larynx and trachea mucosa with formation of laryngotracheostomy.

We used a modern method of local wound treatment together with the endoscopy department staff — vacuum assisted closure (VAC), and the peculiarity of this method is the installation of foam part of drainage system directly into the esophageal lumen at the level of perforation, with complete overlap of the wound defect.

VAC results in isolation from aggressive oral and gastric contents entering the wound defect area, removal of infectious component, reduction of surrounding tissue edema, increased regenerative capacity, increased metabolic activity, increased blood flow, formation of granulation tissue.

All patients with gunshot wounds to the neck admitted to MMCH from the frontline stages of evacuation undergo a comprehensive diagnosis, irrespective of the volume of investigations in the previous stages



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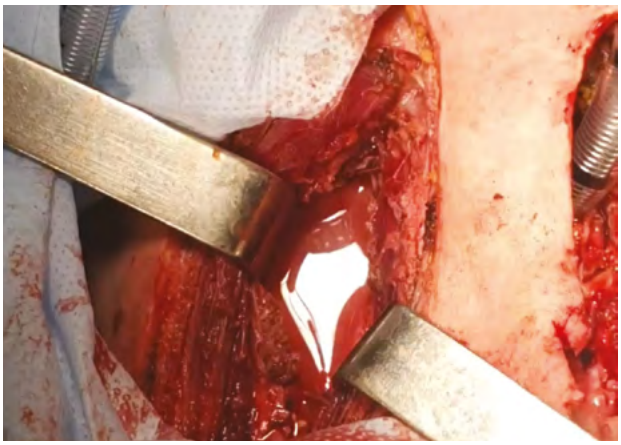

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Fig. 1. A — CT scan of the wounded patient on admission, B — view of purulent wound at revision, C — formed laryngotracheostomy, D — endoscopic picture of the incoming esophageal wound opening, nipple probe installed into the duodenum, E — VAC-system overlapping the wound defects

A B C

Fig. 2. View after surgical treatment of fragmentation perforating penetrating gunshot wound of the neck with damage to the larynx, detachment of the trachea and cervical esophagus: A, B — laryngotracheostoma, esophago- and pharyngostoma are formed; C — pharyngo- and esophagostoma are connected by a 11 mm diameter T-shaped silicone tube

We have not found any data in the literature on the use of VAC method in gunshot wounds of the esophagus.

Clinical case. Patient A. Gunshot fragmentation blind penetrating mine blast wound of the neck with larynx damage, penetrating wound of the cervical esophagus.

Admitted from the evacuation stages on the 4th day after the wound, complicated by neck phlegmon, purulent mediastinitis, bilateral pneumonia. Endoscopic picture of the incoming esophageal wound opening: a laryngotracheostomy was formed. A nipple probe was placed into the duodenum for feeding and a VAC system was installed to overlap the wound defects (Fig. 1).

The second group — neck wounds with complete rupture of the esophagus and damage to the larynx and trachea. In the course of surgical treatment there was performed wide drainage of the wound, excision of nonviable tissues, cartilage fragments, suturing of membranous part of trachea or suturing of membranous part of trachea to larynx in case of complete rupture; suturing of defects of the laryngeal and tracheal mucosa with formation of the lateral walls of a persistent laryngo-tracheostoma and installation of a tracheotomy tube, Mikulich tamponade with water-soluble ointment, daily change of the dressing.

The distal end of the injured esophagus is fixed circularly to the skin with installation of a probe. The proximal end is removed above the esophagostoma with formation of a pharyngostoma. Vacuum aspiration therapy is not applicable in this category of wounded patients.

It is important to note that formation of esophagostoma and pharyngostoma and management of gunshot wounds of the neck with developed purulent complications should be performed in the presence of persistent laryngo- and tracheostoma.

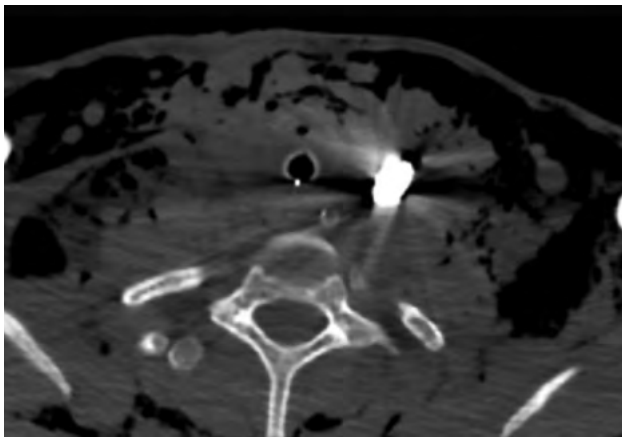
Clinical case. Wounded B. Fragmentation perforating penetrating gunshot wound of the neck with damage to the larynx, detachment of trachea and cervical esophagus. Admitted from the stages of evacuation on the 7th day after the wound, complicated by neck phlegmon, purulent mediastinitis, bilateral pneumonia. View after surgical treatment: laryngotracheostoma, esophago- and pharyngostoma were formed (Fig. 2A, B).

Wounded B. on the 17th day after surgery. A T-shaped silicone tube with a vertical end diameter of 13 mm was placed in the laryngotracheostoma. The vocal folds in the paramedian position were motionless, the voice was of satisfactory soundness. There was no saliva infiltration into the respiratory tract. The pharyngo- and esophagostoma are connected by a T-shaped silicone tube 11 mm in diameter; saliva flows along it into the esophagus with the horizontal end closed, into which a probe is placed for food intake (Fig. 2C).

The third group — a neck wound with damage to the larynx and laryngeopharynx. Surgical treatment includes excision of nonviable tissues, cartilage fragments, suturing of laryngeal and tracheal mucosal defects with formation of persistent laryngotracheostoma. The pharyngeal defect at this level is sutured if possible, and the wound is maintained on tampons with water-soluble ointments.

Clinical case. Wounded C. Fragmentation gunshot penetrating blind mine blast wound of neck with damage to larynx and laryngeopharynx. Admitted on the 3rd day after the wound from the stages of medical evacuation. Severe emphysema. Pneumomediastinum. The patient underwent opening and drainage of cellular spaces of the neck, removal of the fragment, suturing the defect of the sternal sinus on the left side, wound revision, necrectomy of the larynx with formation of persistent laryngostomy and tracheostomy. Subsequently, formation of a laryngos-

A



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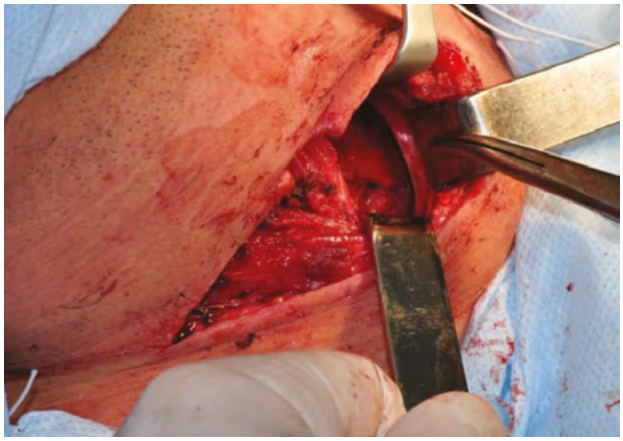

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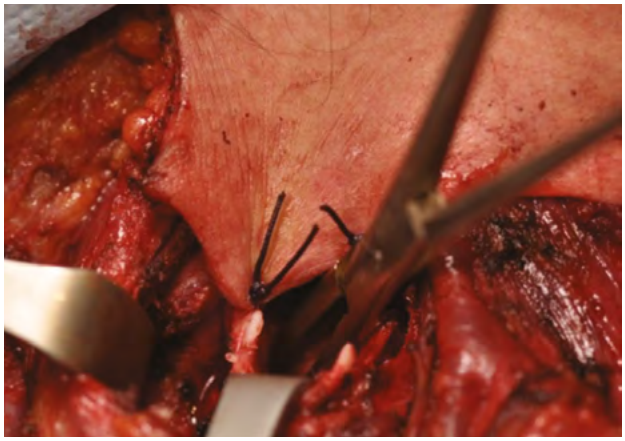

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Fig. 3. Process and posttreatment view of a fragmentation gunshot penetrating blind mine blast wound of the neck with damage to the larynx and pharynx

The technique of dilatation tracheotomy can lead to problems both in the frontline stages of wounded evacuation and in specialized treatment facilities

tomy lumen on a T-shaped silicone tube. Feeding through natural ways, breathing through a T-shaped tube with a closed horizontal end, vocal function restored (Fig. 3).

The fourth group — wound of the neck with damage to the larynx and trachea, without damage to the esophagus. Surgical treatment: suturing membranous part of trachea or suturing membranous part of trachea to larynx, formation of lateral walls of trachea and persistent laryngotracheostoma with installation of tracheotomy tube and tamponade according to Mikulich with water-soluble ointment, daily change of dressing.

Clinical case. Wounded G. Gunshot fragmentation blind penetrating gunshot wound of larynx. Persistent laryngo- and tracheostoma. Endoscopic view of the larynx through a placed T-shaped silicone tube: mobility of the vocal folds is preserved, the laryngeopharyngeal separation mechanism is compensated. Wounded on the 10th day after surgery (Fig. 4).

Attention should be paid to a separate group of wounded, delivered to MMCH from different stages of medical evacuation, who underwent the so-called "puncture-dilatation" tracheotomy in civilian medical institutions. Undoubtedly, in an emergency situation with the development or threat of asphyxia to save the wounded person's life, the throat-separation operation should be performed by the method that the doctor has the skill to perform. However, the technique of dilatation tracheotomy, which is applicable in a planned peaceful situation for short-term access to the trachea, with favorable patient anatomy (long thin neck, no tracheal displacement, etc.), can lead to problems both in the frontline stages of wounded evacuation and in specialized treatment facilities.

Dilation tracheotomy in children is prohibited in all conditions.

Given the peculiarities of the changed contingent of servicemen — increasing number of age, obesity, short neck, enlarged thyroid gland (TG), degenerative changes in the cervical spine with difficulty in extension — per-

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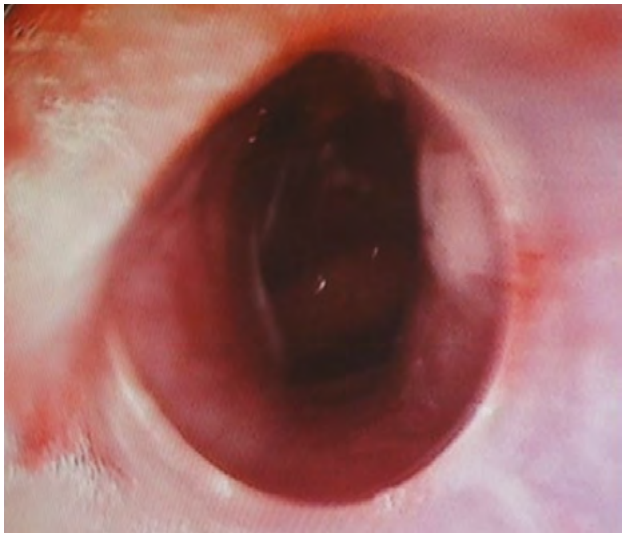

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Fig. 4. View on the 10th day after surgical treatment of a neck wound with laryngeal and tracheal injury, without damage to the esophageal tract

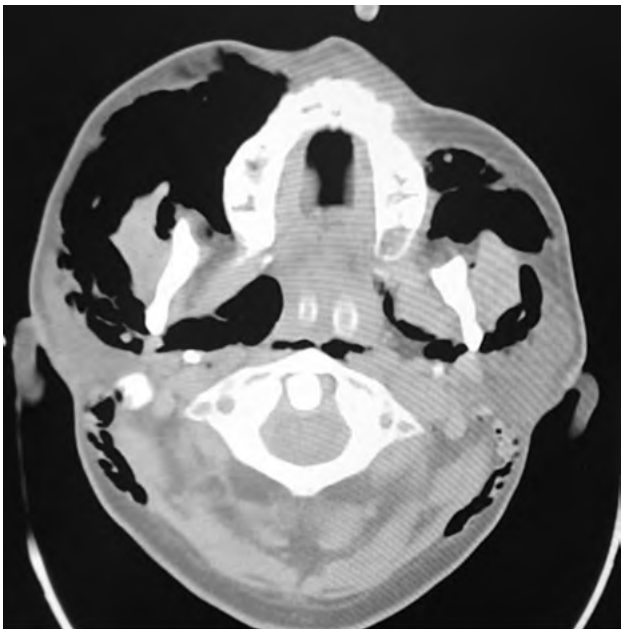


Fig. 5. Fragmentation gunshot penetrating blind mine blast wound of the neck with damage to the larynx and laryngeopharynx. Stages of surgical treatment

forming dilatational tracheotomy on such wounded persons nearly blindly can lead to fatal complications.

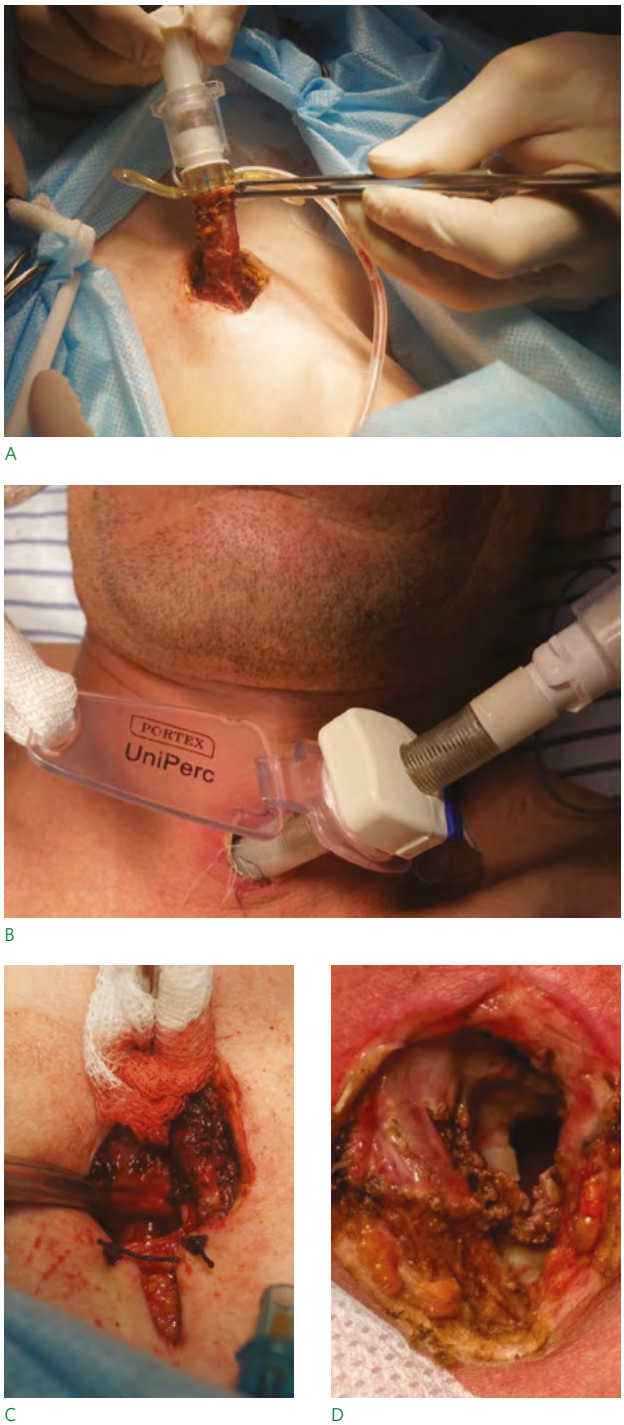
Such wounded patients are difficult to care for. In an emergency situation with the risk of asphyxia with a clogged tracheotomy tube, its replacement becomes a problem due to possible tissue displacement after tube removal, and installation of a new tube through a narrow skin opening and displaced tracheotomy canal may become unfeasible even in the intensive care unit.

Most dilated tracheostomies are tightly sutured around the tracheotomy tube, allowing the contents of the supra-cuff space to enter the cervical cellular spaces and contributing to the progression of neck emphysema to pronounced degrees (Fig. 5).

This problematic situation in a wounded patient requires reshaping the tracheostomy with suturing of the skin to the newly formed tracheal opening

Clinical case. Wounded D. Stages of remodeling after puncture-dilatation tracheostomy: long, shrinking, tightly covering tracheotube canal with bleeding granulation tissue is shrinking when cannula is removed, trachea shifts in relation to the skin, reinsertion of tracheotube is difficult. The upper edges of the tracheal semi-ring are displaced into the lumen, which can form a scar "canopy" up to complete obliteration (Fig. 6A, B).

Considering that the wound after the dilatation tracheostomy is infected, the tracheal semi-rings are fragmented, the wound will heal by secondary tension with the probable development of stenosis (Fig. 6C, D).



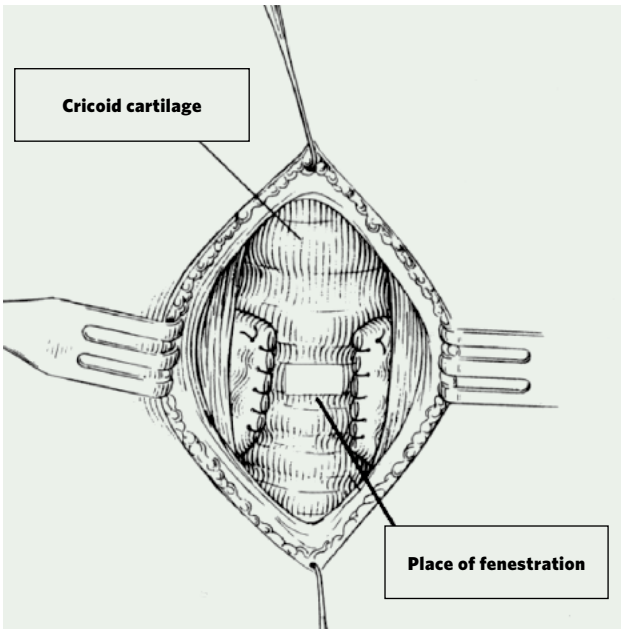
A

B

C

D

Fig. 6. View of the wounded man after puncture-dilatation tracheotomy



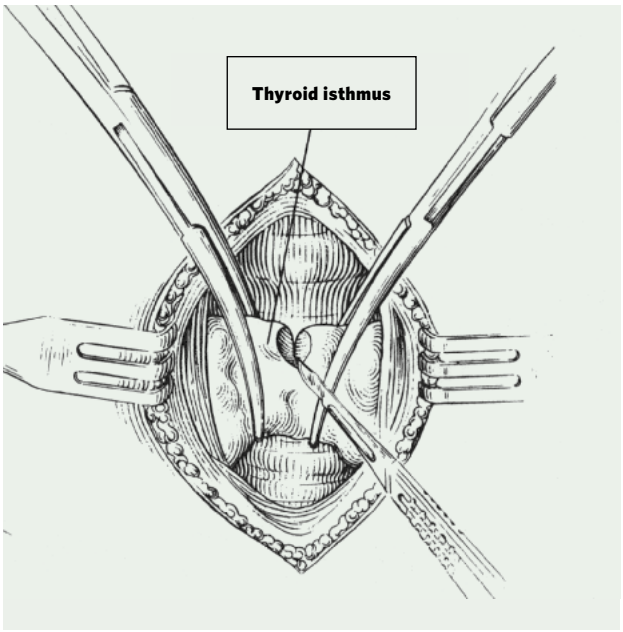


Fig. 7. The order of tracheostomy in the Armed Forces of the Russian Federation

Conclusions. Any type of laryngostomy (laryngotomy, conicotomy, tracheotomy) is allowed to eliminate asphyxia depending on situation, condition of the wounded, availability of strength and means at this stage of medical aid. Atypical tracheostomy should be transformed into typical tracheostomy at the first opportunity.

To create continuity in the care of the wounded and prevent complications of throat resection, tracheostomy in the armed forces should be performed according to the following rules: at the level of 3–4 half-rings with crossing and stitching the isthmus of thyroid and suturing trachea to the skin with four nodal sutures (Fig. 7).

In gunshot wounds of the neck with esophageal damage under conditions of prolonged multistage evacuation the wounds should be managed openly. In the treatment of gunshot defects of the esophagus the use of VAC-method significantly improves the course of the process and accelerates healing.

In case of complete esophageal ruptures, it is necessary for the operation to be completed by formation of a persistent esophagostomy and pharyngostomy. If it is impossible to form an esophagostomy, the distal end is plugged and a gastrostomy is placed for feeding.

In gunshot wounds of the larynx and trachea a permanent laryngo- and tracheostoma is formed after excision of nonviable tissues and suturing of mucosal defects.

Instead of puncture-dilatation tracheotomy when providing surgical care to the wounded in medical institutions at the stages of medical evacuation it is advisable to perform typical tracheostomy according to the above technique.

All stages of airway and esophageal tract reconstruction after wounds should be performed only in specialized medical institutions.

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Current issues of import substitution in the procurement of medical institutions

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Abstract. Currently, the implementation of the import substitution strategy is one of the priorities for the Government of the Russian Federation. The objective of this work is to examine the declared planned indicators of import substitution and their actual achievement, to assess the possibility of meeting the set indicators in 2022, as well as to highlight the information resources and data to be used in the procurement of certain types of medical devices.

Keywords: public procurement, medical devices, national regime, import substitution.

Introduction. The Russian Federation is currently experiencing unprecedented economic pressure. The introduction of sanctions, which violate all norms of international law and the rules of the World Trade Organization, is aimed at creating a deficit in the most sensitive areas, such as the uninterrupted provision of national medicine with high-tech equipment, specialized consumables and medicines. The current situation has shown the urgent need for import substitution in the field of health care.

The national healthcare authorities are faced with the task of assessing the changed market for medical devices and forming their own concept of development, taking into account the new realities.

In 2014, when economic sanctions were imposed against our country, the Russian government set tasks aimed at ensuring import substitution in the domestic economy. On December 31, 2014 the President of the Russian Federation signed the Federal Law "On Industrial Policy in the Russian Federation" (hereinafter Law № 488-FL), developed by the Russian Ministry of Industry and Trade.

In accordance with the norms of the Law 488-FL in order to automate the processes of collection and processing of information required to ensure the implementation of industrial policy and execution of the duties of the federal authorities to stimulate activities in the field of industry, to inform about the support provided to entities of industry and improve the efficiency of information exchange on the state of industry and the forecast of its development, the State Information System of Industry (hereinafter the SISI) was created.

Objective. To conduct a systematic analysis of the established requirements for import substitution in health care, their practical implementation and available tools to achieve the established indicators of an individual medical organization.

Material and methods. The issues of import dependence and measures aimed at leveling the negative consequences of the introduced sanctions policy of unfriendly states are investigated.

According to the estimates of the Government of the Russian Federation, the import dependence in a number of industries currently reaches 90%. Thus, the critical industries from this point of view are as follows:

- machine tool industry (more than 90%);
- Electronics industry (80–90%);
- light industry (70–90%);
- pharmaceutical medical industry (70–80%);
- heavy engineering (60–80%);
- machinery for food industry (60–80%) [1].

At the beginning of this year, the Ministry of Health of Russia conducted an analysis of the market of medical devices and came to the conclusion that there is a risk of a deficit of about 254 items of critical medical devices. The list includes imported endoprostheses and their components used in traumatology and orthopedics, catheters and consumables for cardiovascular surgery and neurosurgery, devices, instruments, components and expendables for endosurgery, anesthesia and intensive care, transplantology and dialysis. In addition, there is a dependence in the procurement of medical equipment, especially high-tech, demanded in the framework of the national project "Healthcare". [2].

If to consider the public procurement as institute of business stimulation, the consecutive legal regulation in the sphere of the national regime in July 2020 has led to adoption of new amendments to the Federal law from 05.04.2013 № 44-FL "On contract system in sphere of procurement of goods, works and services for provision of state and municipal needs" (hereinafter referred to as the Law № 44-FL). Section 30.1 "Peculiarities of Procurement for the Purposes of Achieving a Minimum Procurement Share by the Customer" was introduced, establishing the obligation of the state and municipal customer to make a certain volume of procurement of goods (including goods supplied in the course of work and services to be procured) included in the register of Russian industrial products, in the unified register of Russian radioelectronic products, the Eurasian register of industrial products of member states of the Eurasian Economic Union (hereinafter EAEU).

Based on the provisions of Section 30.1 of Law № 44-FL there was issued Russian Government Decree of 03.12.2020 № 2014 "On the minimum mandatory share of procurement of Russian goods and its achievement by the customer" (hereinafter the GD № 2014), which determines the list of goods in the procurement of which customers are required to consistently switch from imported products to domestic products. Starting from 2021, all customers are obliged to achieve annually the minimum share of procurement of Russian goods, including those supplied in the performance of work and services, established by Appendix №. 1 to GD № 2014.

However, the actual execution of GD No. 2014 did not come close to the forecast values. So, in April 2022, the deputy head of the Federal Treasury A. Katamadze announced the results of compliance with the requirements to achieve the share of Russian goods in 2021, according to which the plan for the purchase of Russian ultrasound machines in 2021 was implemented only by 50%, while in 2021 the state customers were to buy at least 60% of ultrasound machines from Russian manufacturers. In reality, the share was 28%.

The quota for the purchase of prosthetic limbs was set at 45%, but only 9% was fulfilled. For optical devices and photographic equipment the quota was set at 50%, but the implementation was 21%. Among all items of Russian products planned for purchase in this format, in 2021 buyers managed to select all quotas on 51 categories out of 99 [3].

In September 2022, the Accounts Chamber of the Russian Federation published a report on the analysis of anti-crisis procurement measures taken during the pandemic. According to the Accounts Chamber, the most effective and popular of all the measures implemented was the possibility to make purchases from a single supplier, if they are urgent and used to prevent the pandemic. As a result of its application, the number of contracts with a single supplier in 2020 increased by 15.6 times compared to 2019, in 2021 — by 7.8 times [4].

The positive assessment of the measures taken during the "lockdown" period predetermined the introduction of temporary measures by the Government of the Russian Federation in the current year, aimed at maintaining the stability of the economy, such as the possibility of increased advance payment, the right to not establish a contract execution assurance, cancellation of penalties, reduction of payment terms under contracts, the possibility to change the essential conditions of the contract. The cases of conclusion of contracts without competitive procedures were supplemented and expanded.

By the end of 2022, there was an unprecedented situation with the multiplicity of cases of contract conclusion with a single supplier, as well as with the volume of such purchases in value terms. According to the results of the Ministry of Finance's monitoring for the last three quarters of 2022, the share of contracts concluded with a single supplier amounted to 24.7% of the total volume of concluded contracts in value terms. The growth in the share of purchases from a single supplier as compared to the same period of 2021 increased by 78%, including 13,306 contracts worth a total of 786.1 billion rubles, concluded on the basis of temporary cases determined by decisions of the RF Government and

supreme executive authorities of subjects of the Russian Federation, including:

- on the basis of decisions of the Government of the Russian Federation (Part 1 of Section15 of the Federal Law of 08.03.2022 № 46-FL) — 210 contracts worth 2.2 billion rubles;
- on the basis of decisions of the supreme executive authorities of the Subjects of the Russian Federation (Part 2 of Section 15 of the Federal Law of 08.03.2022 № 46-FL) — 13,096 contracts worth Rb 783.9 billion rubles. [5].

From November 2022 ten agencies were granted the right to procure goods, works and services from a single supplier for a special military operation, as well as to perform special tasks to ensure the defense and security of the state under Clause 56 Part 1 Section 93 of the Law № 44-FL. In addition, the limit of 50 million rubles on the total annual number of purchases made on the basis of Clause 4, Part 1 of Section 93 of the Law № 44-FL was canceled for customers referred to in Clause 56, Part 1 of Section 93 of the Law.

Considering the introduction of new cases of purchases from a single supplier, as well as the fact that the temporary measures taken in 2022 were extended until the end of 2023, it should be assumed that the share of non-competitive purchases will steadily grow next year.

Conclusions on management decisions at the level of the Government of the Russian Federation and the individual budget institution, as well as an evaluation of the effectiveness of measures currently being taken, will be made in future periods.

It is worth noting the position of the Russian Ministry of Industry and Trade — the regulator of import substitution, outlined in a letter of 27.04.2022, № OV-39122/12, which emphasizes the need to comply with the national regime of procurement, including the requirements of the GD RF № 616, as well as the obligation of the customer to achieve the established share of domestic procurement. According to the ministry, it is necessary to conduct competitive purchases of goods, works and services, including compliance with the norms of the national regime, if the customer has such an opportunity. At the same time, the ministry strongly recommends that customers plan the procurement of goods for which there are requirements to give priority to domestic goods, considering the data on industrial goods that meet the requirements of the end consumer, available in the register of Russian industrial products, in the unified register of Russian radioelectronic products, the Eurasian register of industrial goods of EAEU member states.

The share of domestic procurement is determined not in quantitative, but in value terms. Achieved indicators based on the results of the year are reflected in the mandatory report published by the customer not later than April 1. The report is formed on the basis of information from the register of contracts.

Consequently, the customer, when establishing a ban, restrictions or conditions for the admission of goods for such purchases, is obliged to achieve the minimum share of purchases of Russian goods stipulated by GD No. 2014.

The establishment of requirements for national regime is provided only in the implementation of competitive procedures, except for the ban on the admission of goods, established by the Government of the Russian Federation Decree № 616, which means that the annual report, formed on the basis of information from the register of contracts, cannot include information on purchases made from a single supplier, except in cases of procurement from a single supplier in accordance with Clauses 24, 25 Part 1 Section 93 of the Law № 44-FL, because in these cases, compliance with the national regime was mandatory.

Besides the plan of achieving the share of procurement of domestic products, one of the absolute directives of GD № 2014 is the norm established by Clause 3 on the procedure for determining the initial (maximum) price of a contract (hereinafter IMPC) or the price of a contract concluded with a single supplier (contractor, executor) for the supply of goods, works and services, taken into account for the purpose of achieving a minimum share of purchases.

Thus, when applying the method of comparable market prices (market analysis), the customer must send the price inquiry stipulated in Part 5 of Section 22 of Law No. 44-FL on the price of goods exclusively to entities in the field of industry, information on which is included in the SISI. If there is no information on entities in the SISI or if there are not enough companies to determine the maximum price (less than three), according to the position of the Ministry of Industry and Trade of Russia, when calculating the initial (maximum) contract price, the customer must:

- record that the required data is missing or not presented in full (make a screenshot from the SISI), which will be a justification for a future report on the failure to meet the established minimum share;
- send information on the absence of the required data in the SISI to the Ministry of Industry and Trade of Russia by e-mail: Metod@minprom.gov.ru [6].

If there are less than three entities supplying identical goods in the SISI, the customer sends a request for price information to suppliers of goods originating from the EAEU member states, information on which and the goods supplied by them is contained on the official UPIS website in the register of contracts concluded under Law № 44-FZ.

Table 1. Correlation of registers of the state information system of industry with normative-legal acts (NLA) regulating the national procurement regime

Name of registry (address)	NLA, under which the origin of the products is confirmed
Register of Russian industrial products (https://gisp.gov.ru/pp719v2/pub/prod/)	Decrees of the Government of the Russian Federation № 616, 617 and 2014
Unified Register of Russian Radioelectronic Products (https://gisp.gov.ru/rep/marketplace/#/products)	Decrees of the Government of the Russian Federation № 616, 878 и 2014
Eurasian Register of Industrial Goods (https://erpt.eecommission.org/)	Decrees of the Government of the Russian Federation № 616, 878 и 2014
Russian software registry (https://reestr.digital.gov.ru/)	Decrees of the Government of the Russian Federation № 1236
Eurasian Software Registry (https://eac-reestr.digital.gov.ru/)	

With regard to the last condition, in our opinion, there is unjustified discrimination against suppliers. For example, the Law № 44-FL along with open procurement provides for closed procedures, information about which is not published on the official website of the UPIS, but is necessarily included in the register of contracts. Counterparties in such procurements carry out their activities on specialized electronic platforms. Based on the disposition of Paragraph 3 of Clause 3 of GD № 2014, the customer cannot receive price offers from suppliers of goods originating from the EAEU countries if such suppliers are participants in closed procurements only, despite their actual experience of supplying identical goods. But it is fair to note that not being able to use price proposals from such suppliers does not mean that there is a ban on concluding supply contracts with them.

To summarize the provisions governing the procedure for determining the price list, it can be concluded that, according to GD № 2014:

- the customer is obliged to send requests for price information to entities registered in the SISI;
- Russian legislation does not provide for the obligation of industrial entities, information on which is included in the SISI, to respond to customer requests and provide price information on the product.

In addition, the form, content and terms for the provision of such data by industrial entities, information on which is included in the SISI, have not been approved by law.

The customer has the right to send requests for price information to companies which are not registered in the SISI, on the condition that such companies offer products manufactured in the countries which are members of the EAEU and have supply experience confirmed by information from the register of contracts published in the UPIS.

It is prohibited to use information on goods received from foreign manufacturers for the purposes of justifying the IMPC.

Thus, the customer's officials, who are personally responsible for violating the legislation of the Russian Federation, are obliged to fulfill the requirements of GD № 2014 by searching for the required purchase item in regularly updated registers, comparing information on the technical characteristics of goods, which in fact leads to the situation where the SISI becomes the only data source for the customer and requires employees to thoroughly study all registers and constantly work with this resource.

Let's review the SISI tools that will be useful for a medical institution when planning and making its purchases.

If the goods to be purchased fall under the requirements of the national regime established by Section 14 of Law № 44-FL, the customer must first search and compare them in the relevant registers, according to Table 1.

Search in the GISP catalogs is implemented by a number of criteria, including the All-Russian Classifier of Products by Type of Economic Activity 2 (ARCPTE2), industry, region, and product manufacturer. Advanced search allows searching of products by description, including product type, Commodity Nomenclature of Foreign Economic Activity (CNFEA); catalog of goods, works and services (CGWS), etc., as well as by information on standardization and specifications.

In March 2022, the Import Substitution Exchange was launched, which is implemented on the basis of SISI and Gazprombank's trading platform (GPB TP) and is a service that allows manufacturers and suppliers of industrial goods (domestic and imported) to publish information about the products they produce and supply, and customers to find Russian analogues of imported goods and research available imported goods in circulation.

A. Smirnov, General Director of the Association of Organizations of Defense Industry Complex Manufacturers of Medical Devices and Equipment, expressed the following opinion on the new information service: "Today the trading platform SISI (Exchange) is one of the effective ways to develop diversification programs, import substitution and support of the domestic manufacturer. The fundamental point for our industry is to make it more convenient for bona fide manufacturers to participate

in public procurement of medical devices both at the federal and regional levels, as well as to increase their competitiveness".

The list of competitive Russian products, the use of which is required for the implementation of national projects and the integrated plan of modernization and expansion of the main infrastructure until 2024, including 4755 items of various goods, is placed and kept up-to-date in the SISI. For navigation, medical products are grouped in the following sections:

- National project "Health care", further 108 items;
- The national project "Science", then — 168 items;
- The national project "Demography", the subprogram "Strengthening of Public Health", further — 28 items.

In March 2022 in pursuance of one of the basic legal principles "A norm without a sanction is dead" draft amendments to the Code of Administrative Offences of the Russian Federation were presented that envisage introduction of fines for violation of "national procurement regime", including non-compliance with the annual minimum share of purchases of medical products from Russia and EAEU countries. Therefore, the described functionality of the SISI is likely to become in the near future the main source of information for the customer when analyzing the available market conditions for products to be procured.

Results, discussion, and conclusions. When planning and carrying out procurement, a medical organization should be guided by an import substitution strategy.

Temporary measures in government procurement to maintain the sustainability of the economy, adopted in 2022 and extended to 2023, do not eliminate the existing obligation of the medical institution to purchase domestic products. Competitive methods of determining the supplier should continue to be the priority method of procurement.

When planning the purchase of products, including those supplied in the provision of services and the performance of work, the customer must be guided by information from the SISI resources both in justifying the IMPC and in describing the product.

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