

# Treatment of wound Infection in case of Gunshot Wounds and Objective Criteria of its Effectiveness

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## ANNOTATION

**Annotation.** The analysis of complex treatment of 48 patients with infectious complications of gunshot wounds of the extremities was carried out. In 30 patients - using the method of treatment developed by the authors (RF patent No. 2281126). For an objective assessment of the applied treatment method, the following criteria were used: clinical and biochemical blood tests, microbiological, cytological and immunological studies. Studies of the functional activity of the B-system of lymphocytes showed that patients with wound infection have a significant decrease in class M and G immunoglobulins. The combination of hyperbaric oxygenation with ultraviolet blood irradiation has a pronounced bactericidal and detoxifying effect, and also accelerates the recovery of the body's detoxification function, creating optimal conditions for wound healing. The proposed method of treatment improves the results of treatment and reduces possible complications.

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## INTRODUCTION

With a gunshot wound, complex pathomorphological processes occur in the body, which lead to primary multiple organ failure.<sup>[7]</sup> With the progression of the wound process, a syndrome of multiple organ failure of a secondary nature is formed, which occurs under the influence of microbial invasion and endogenous intoxication.<sup>[1,3]</sup> Against the background of such significant pathological changes in the body of the wounded, there is a difficult task of treating infectious complications of a gunshot wound.<sup>[2,4]</sup> This problem should be solved only by a complex way of direct impact on the wound, suppression of microflora and correction of homeostasis disorders.<sup>[5,6]</sup>

## MATERIAL AND METHODS

48 patients with various forms of infectious complications of gunshot wounds were under observation. Age ranged from 18 to 60 years, and the time of injury from 6 to 28 days. According to the nature of the wounding projectile, the victims were distributed as follows: single and multiple bullet wounds were in 26 people, shrapnel wounds and mine-explosive injury - in 22 wounded. Multiple and combined injuries were noted in 19 people and injuries of one of the segments - in 29. Infectious complications were as follows: purulent-resorptive fever was noted in 17 patients, septicemia - in 10 patients, and in 21 - local changes in the form of a local purulent-necrotic process. Wound osteomyelitis was diagnosed in 21 patients.

Septicemia was noted in 20.8% of patients, which was characterized by a general severe condition of the patient, high fever, and impaired activity of various functional systems. Multiple organ failure progressed in them despite the active impact on the focus. Local purulent-necrotic changes were noted in 43.8%, they, in turn, were subdivided as follows:

### KEYWORDS:

Gunshot wounds,  
Hyperbaric oxygenation,  
Infectious complications,  
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putrefactive infection was noted in 10 patients and pseudoseptic course with a latent period of development of an infectious wound complication - in 11 patients.

The reason for the development of infectious complications of gunshot wounds of the extremities was the mistakes made at the previous stages of treatment. In 15 (31.3%) of the wounded, insufficiently radical primary surgical treatment of the wound was noted. In 14 (29.2%), wound treatment was not performed, limited to skin dissection; primary sutures were placed in 9 (18.7%) wounded on segments with a large muscle mass and in 10 (20.8%) of the wounded, inadequate and insufficiently radical repeated surgical interventions were noted due to complications that had developed.

The main group consisted of 30 patients in the treatment of which we applied an integrated approach, which consists in the following: adequate therapy of the syndrome of secondary multiple organ failure and correction of homeostasis; early secondary surgical treatment; rational antibiotic therapy and other antimicrobial chemotherapy; limb immobilization; repeated surgical interventions and rehabilitation measures. With a septic process, depending on the severity of the condition, one has to resort to palliative operations: a wide opening of the main or metastatic focus and adequate drainage, then staged necrectomy was performed.

Infectious complications of gunshot wounds were accompanied by a pronounced violation of the water and salt balance, protein metabolism, acid-base balance. The patients were in a state of dehydration, anemia, hypoproteinemia. Infusion therapy was carried out with the aim of replenishing the volume of circulating blood, eliminating dehydration, detoxification, regulating electrolyte balance, replenishing protein composition, enriching with vitamins, restoring microcirculation in tissues and for parenteral nutrition.\

Before determining the type of microflora and its sensitivity to antibiotics, broad-spectrum antibiotics were used, which were administered parenterally. Considering that anaerobic microflora is present in gunshot wounds, and antibiotic therapy for anaerobic infections is not always successful, metronidazole derivatives were used. Metronidazole was administered intravenously 3-4 times a day, depending on the severity of the condition.

For immobilization, extrafocal osteosynthesis with external fixation devices was used. Fixation with the Ilizarov apparatus of two rings was most often used, which facilitated manipulations and dressings; after the inflammatory process subsided, the apparatus was completed.

In 12 patients with sepsis, we used hyperbaric oxygenation in complex treatment, and in 18 patients - hyperbaric oxygenation (HBO) and ultraviolet blood irradiation (UBI).

The control group consisted of 18 patients who had the following complications of gunshot wounds: purulent-resorptive fever in 7 patients, septicemia in 3 and local changes (local purulent-necrotic processes) in 8 patients. They also underwent complex treatment, but without HBO and UBI of blood.

For hyperbaric oxygenation, the domestic installation "OKA MT" was used. In the presence of sepsis and suspicion of

anaerobic infection, a high pressure of 2.0-2.5 atm was used - 8-10 sessions each. In patients with extensive purulent wounds, but without clinical manifestations of sepsis, a lower pressure of 1.3-1.5 atm for 40-60 minutes, 6-7 sessions every other day.

UBI of blood was applied to patients using the apparatus MD-73M "Izolda" of domestic production, in which the patient's blood is irradiated while flowing through a flat quartz cuvette. The volume of irradiated blood is 1-2 ml per 1 kg of the patient's body weight, the irradiation exposure is 10-15 minutes. The radiation dose was 0.6-0.9 J. The number of sessions was determined by the severity of the patient's condition and the course of regeneration processes in the wound and ranged from 5 to 7, alternating every other day.

Hyperbaric oxygenation in complex treatment was used in 12 patients with infectious complications of gunshot wounds. Purulent-resorptive fever was diagnosed in 5 patients of the ball, septicemia in 2, and local purulent-necrotic changes in 5. HBO mode was chosen individually. Patients with septicemia received the greatest number of sessions.

HBO therapy had a multivalent effect and affected almost all life support systems of patients.

After 1-2 HBO sessions, 41.7% of patients showed an improvement in their general condition: lethargy and weakness, vegetative phenomena associated with intoxication disappeared.

The respiratory rate decreased from  $25.8 \pm 0.1$  per minute to  $24.6 \pm 0.2$  per minute ( $P < 0.05$ ). After 3-4 sessions it was  $23.1 \pm 0.1$  ( $P < 0.05$ ), and after 6-7 sessions it was  $21.3 \pm 0.3$  ( $P < 0.05$ ). Against the background of improvement in external respiration, gas exchange also improved. So  $Po_2$  after 1 session increased from  $77.2 \pm 0.31$  mmHg to  $86.2 \pm 0.42$ , after 3-4 sessions up to  $91.2 \pm 0.23$  mm. rt. Art., and after 6-7 sessions up to  $94.7 \pm 0.31$ .

In the course of treatment in the main group, significant changes were noted in the functions of the main detoxification systems of the body. This was expressed primarily in the positive direction of indicators reflecting the functional state of the liver. Total bilirubin decreased from  $34.27 \pm 2.23$   $\mu$ mol/l to  $20.21 \pm 1.71$   $\mu$ mol/l ( $P < 0.01$ ) after a course of hyperbaric therapy. Total protein increased from  $54.8 \pm 2.3$  g/l to  $64.1 \pm 2.1$  g/l ( $P < 0.05$ ). Residual nitrogen decreased from  $46.7 \pm 3.2$  mg% to  $30.1 \pm 4.2$  mg% ( $P < 0.01$ ).

Hyperbaric oxygenation significantly influenced the immune status of patients. After 6-7 sessions of HBO-therapy, stimulation of the T- and B-systems of lymphocytes, an increase in the level of M and G immunoglobulins was observed. Whereas in the control group, immunosuppression persisted even after wound healing (Table 1).

By the 5th-6th HBO-therapy session (on days 11-12), granulations filled the entire wound, which contributed to faster wound healing, secondary sutures or skin grafting. The terms of wound healing were  $33.4 \pm 1.3$  versus  $56.7 \pm 2.9$  in the control group.

In the complex treatment of 18 patients with infectious complications of gunshot wounds, hyperbaric oxygenation and

ultraviolet blood irradiation were used. Purulent-resorptive fever was diagnosed in 5 patients, septicopyemia was also diagnosed in 5 patients, and local purulent-necrotic changes in 8 patients.

UB irradiation of blood and hyperbaric oxygenation alternated, i.e. the patient received one session of HBO or UBI of blood per day. As a rule, they started with UB irradiation of blood, but if an anaerobic infection was suspected, a session of hyperbarotherapy was performed on the first day.

On the day of admission, surgery and the first session UB irradiation of blood were performed, some patients during the first session noted "tingling" in the wound area, a taste of metal in the mouth, slight dizziness, all these phenomena disappeared on their own within 5-10 minutes after the session. The next day, HBO was carried out according to the accepted methodology. After the first sessions of HBO and UB irradiation of blood, a distinct therapeutic effect was revealed: the patients' state of health improved, intoxication decreased, and hyperthermia decreased. In the leukocyte blood formula,

a decrease in ESR, an increase in leukocytes due to basophils and lymphocytes were noted. Respiratory rate decreased from  $26.7 \pm 0.07/\text{min}$  to  $23.72 \pm 0.13/\text{min}$  ( $P < 0.05$ ). After 3-4 sessions it was  $22.81 \pm 0.13$  ( $P < 0.05$ ), and after 6-7 sessions it was  $20.03 \pm 0.12$  per minute ( $P < 0.01$ ). An improvement in gas exchange was noted, so  $Po_2$  after one session of UVR and HBO increased from  $77.3 \pm 0.23$  mm Hg. up to  $90.5 \pm 0.42$  mm Hg, and after 3-4 sessions up to  $97.3 \pm 0.51$  mm Hg ( $P < 0.01$ ). Total bilirubin decreased from  $38.3 \pm 3.34$   $\mu\text{mol/l}$  to  $16.07 \pm 1.92$  ( $P < 0.01$ ), while at the same time in the group where only HBO was performed, it decreased to  $20.21 \pm 1.71$  ( $P < 0.05$ ). A trend towards a decrease in the content of bilirubin and its components was equally noted both in patients without pronounced signs of hepatic and renal insufficiency, and in patients with hepatic and renal insufficiency. Total protein increased from  $55.3 \pm 1.3$  g/l to  $67.3 \pm 1.7$  g/l ( $P < 0.01$ ). Residual nitrogen also decreased from  $45.9 \pm 3.7$  to  $28.5 \pm 2.8$  ( $P < 0.01$ ).

The effect of including HBO and UV irradiation of blood in the complex therapy of patients with sepsis depends on the initial

**Table 1:** Change in the dynamics of the immune status indicators with the use of hyperbaric oxygenation.

Indicators	Donors	Patients	
		Before HBO	After the HBO course
T- lymphocytes in %	62,5 ± 5,6	30,3 ± 4,5	49,6 ± 5,8 P<0,05
Abs.number of cells/ml	1153 ± 112	840 ± 49	985 ± 37 P<0,05
Active in %	20,0 ± 3,4	2,1 ± 0,5	3,3 ± 1,5
Abs.number in kl/mkl	206 ± 13,3	16,8 ± 3,4	30,3 ± 4,7 P<0,05
B-lymphocytes in %	18,4 ± 1,2	13,3 ± 2,4	14,4 ± 2,2
Abs. number in cl/mcl	395 ± 18,2	305 ± 29,3	375 ± 15,4
Immunoglobulin G	12,49 ± 0,26	4,37 ± 0,19	8,18 ± 0,43 P<0,05
Immunoglobulin M	1,32 ± 0,05	0,77 ± 0,13	0,89 ± 0,06

**Table 2:** Results of quantitative accounting of microflorain dynamics

Days of research	Control group	HBO	HBO+UBI
1 day	1,0·10 <sup>□</sup>	2,3· 10 <sup>□</sup>	8,1· 10 <sup>□</sup>
3 days	1,2·10 <sup>□</sup>	1,1· 10 <sup>□</sup>	1,0· 10 <sup>□</sup>
5 day	4,2 ·10 <sup>□</sup>	3,4 ·10 <sup>□</sup>	2,0· 10 <sup>3</sup>
9 day	6,4 ·10 <sup>□</sup>	3,0·10 <sup>3</sup>	3,7· 10 <sup>2</sup>

**Table 3:** Change in the dynamics of immune status indicators under the influence of hyperbaric oxygenation and ultraviolet blood irradiation

Indicators	Donors	Patients	
		Before the treatment	After the course of HBO+ UB irradiation of blood
T- lymphocytes in %	62,5 ± 5,6	31,4 ± 2,4	56,4 ± 6,9 P<0,01
Abs.number of cells/ml	1153 ± 112	890 ± 42,5	1090 ± 67,5 P< 0,05
Active in %	20,0 ± 3,4	3,2 ± 1,1	4,6 ± 2,3
Abs.number in kl/mkl	206 ± 13,3	26,7 ± 7,3	47,4 ± 5,0 P<0,05
B-lymphocytes in %	18,4 ± 1,2	12,3 ± 2,4	15,6 ± 2,8
Abs. number in cl/mcl	395 ± 18,2	310 ± 12,3	380 ± 24,2 P<0,05
Immunoglobulin G	12,49 ± 0,26	4,56 ± 0,21	9,63 ± 0,17 P<0,01
Immunoglobulin M	1,32 ± 0,05	0,79 ± 0,11	0,91 ± 0,07

Table 4: results of treatment of patients

Methods of treatment	terms of wound cleansing	The timing of the appearance of granulations	The timing of wound healing
HBO+UFO blood	5,2 ± 0,3	5,9 ± 0,7	27,8 ± 1,6
HBO	6,8 ± 0,4	7,6 ± 0,3	33,4 ± 1,3
Tradition treatment	12,9 ± 1,4	13,7 ± 0,4	56,7 ± 2,9

(The data are statistically reliable  $P < 0.05$ ).

state of the macroorganism, however, already in the first 2-3 sessions, it allows us to note the transition of cytograms of the degenerative-necrotic type to the degenerative-inflammatory or to the first phase of the reparative period.

There was a shift in the pH-metry of the wound contents towards alkalization. In the interval of 3-5 sessions, the appearance of islands of juicy pink granulations was noted, which, by the end of the course, capture most of the wound surface. By this time noted the stabilization of the pH-metry in the wound within 7.3 - 7.6.

After 5-6 sessions of HBO and UV irradiation of blood, the wounds decreased in size, became superficial, maturation of granulation tissue continued, it became dense, fine-grained. This made it possible to start a staged convergence of the wound edges, to apply secondary sutures, or to perform autodermoplasty.

In the control group, during these periods, the wounds were cleansed of necrotic tissues, serous, seous-purulent exudate continued to stand out. Although the growth of granulation tissue was determined, the wound defect remained deep. The terms (time) of wound cleansing in the main group were  $5.2 \pm 0.3$  days, the average time for the appearance of granulations was  $5.9 \pm 0.7$  days, and the time for wound healing was  $27.8 \pm 1.6$ .

In the complex treatment with the use of HBO and ultraviolet blood irradiation, on the 5th day in smears, the percentage of altered neutrophils was low -  $14.1 \pm 1.9$ . In contrast to the control group, neutrophils in a state of phagocytosis, immature mononuclear elements and macrophages, as well as a small amount of fibroblasts, were often encountered.

On the 9th day there was a decrease in the number of immature mononuclear elements and macrophages, an increase in the percentage of young and mature fibroblasts. On the 11-12th day, in comparison with the previous period, a positive dynamics of the wound process was revealed, which characterizes the growth of the elements of the fibroblastic series, its mature forms.

Therefore, in the complex treatment of infectious complications of gunshot wounds with the use of HBO and UV irradiation of blood, already starting from 3-5 days, cytologically, activation of the reparative process is noted.

Microbiological studies included the study of microflora, its sensitivity to antibiotics and the quantitative accounting of microorganisms. In the vast majority of cases, *Staphylococcus aureus* was sown both in monoculture and in association with other microflora (51.7%), *Pseudomonas aeruginosa* accounted for 16.2%, *ps. vulgaris* - 12.9%, *B. fragilis* - 9.6% and *E. coli* - 9.6%. The sown aerobic microflora was sensitive to erythromycin, gentamicin, lincomycin, cefazolin, cefataxime and insensitive to penicillin, oxacillin, carbenicillin. Anaerobic microflora was sensitive to chloramphenicol, metronidazole, cefataxime and slightly sensitive to rifampicin and carbenicillin.

Before surgical treatment of the wound, 1 g of tissue contained from  $10^7$  to  $10^9$  bacteria. In the process of surgical treatment and exposure to HBOT sessions and UV irradiation of blood, a

decrease in the bacterial load to  $10^3 - 10^5$  microorganisms was noted on days 5-6, with a further decrease to  $10^3$  (an average of  $3.7 \cdot 10^2 \pm 3.6 \cdot 10$  bacteria), while in the control group, these values were reached on the 17-18th day (table 2).

## RESULTS OF IMMUNOLOGICAL STUDIES

In 10 patients with infectious complications of gunshot wounds of the extremities, rosette formation was studied with ram erythrocytes (T-cells) and with the zymosan-complement complex (B-cells) before treatment and during the use of HBO and UVI of blood. We also studied the content of immunoglobulins before and during treatment.

Studies have shown that in the stage of stress and catabolic disorders, there is a significant decrease in the percentage and absolute content of T-lymphocytes in peripheral blood, especially the number of "active" T-cells that form rosettes with 10 or more red blood cells. A decrease in B-lymphocytes was also noted. Studies of the functional activity of the B-system of lymphocytes showed that patients with wound infection have a significant decrease in class M and G immunoglobulins.

As a result of complex treatment with the use of hyperbaric oxygenation and UV irradiation of blood, a significant increase in T- and B-lymphocytes and immunoglobulin G ( $P < 0.05$ ) was noted already after 5-6 sessions (table 3).

### Results of treatment of patients.

In 12 patients, hyperbaric oxygenation was used in complex treatment. When HBO was used in the complex treatment of infectious complications of gunshot wounds, wound cleansing was noted after  $6.8 \pm 0.4$  days, granulations appeared after  $7.6 \pm 0.3$  days, and complete wound healing was noted after  $33.4 \pm 1.3$  days. In the process of treatment, 6 patients on the 6-7th day began a staged convergence of the wound edges by the method of dosed stretching, secondary sutures were placed in 3 patients on the 8-9th day, and 3 patients underwent free autodermoplasty with a split flap. No complications were noted in this group.

In the next group, in the complex treatment of 18 patients, hyperbaric oxygenation and UV irradiation of blood were used. This group had a more severe contingent of patients. Cleansing of wounds from necrotic tissues was noted at  $5.2 \pm 0.3$  days, the time of appearance of granulations after  $5.9 \pm 0.7$  days. Complete wound healing was noted after  $27.8 \pm 1.6$  days (Table 4).

The use of hyperbaric oxygenation and UV irradiation of blood in the complex treatment allowed us to start a staged convergence of the wound edges by the method of dosed stretching on the 5-6th day, followed by the application of secondary sutures in 6 patients, secondary sutures were applied in 5 patients and free autodermoplasty with a split flap was applied. In addition, 4 patients underwent necrosectomy with extrafocal transosseous osteosynthesis.

It should be noted that in the treatment of 12 patients with infectious complications of gunshot wounds of the extremities, staged convergence of the wound edges was used for early wound closure, the method of dosed stretching proposed by us allowed us to dynamically monitor the course of the wound



process and close wound defects with a full-thickness flap. Recovery was noted in all groups.

Functionally, good and satisfactory results were obtained in 25 patients. In 4 patients, various dysfunctions of the limbs were noted, associated with the severity of the injury (defects in the diaphysis and joint-forming surfaces of the bones), which require long-term rehabilitation treatment. A rare complication in the form of bilateral endophthalmitis (septic etiology), with loss of vision in one eye, was noted in one patient.

## CONCLUSIONS

1. The use of hyperbaric oxygen therapy, UV irradiation of blood and interstitial electrophoresis of antioxidants in the complex treatment of infectious complications of gunshot wounds of the extremities is pathogenetically justified.
2. Hyperbaric oxygen therapy against the background of complex therapy of purulent-septic complications compensates for oxygen deficiency and promotes the mobilization of the body's defense reactions, restores the function of external respiration, corrects hemodynamic disorders, and contributes to the correction of secondary immune deficiency.
3. Combination with UV blood irradiation has a pronounced bactericidal and detoxifying effect and accelerates the recovery of the body's detoxification function, creating optimal conditions for wound healing.

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