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Research Article

Comparative Evaluation of the Effectiveness of Methods for the Treatment of Surgical Soft Tissue Infection

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Keywords: Surgical infection of soft tissues; Physical methods of treatment; Microbiological characteristics

Abstract

Background: The presence of a multifaceted microbiological etiological factor of surgical infection and differentiated sensitivity to antibacterial drugs determines the need to develop more effective means and methods of influencing the purulent microflora of wounds. Physical treatment factors, in particular, low-frequency ultrasound and ionised plasma flows, should be considered promising for solving this problem.

Materials and methods: The research was carried out based on the Scientific Center of Microbiology and the clinic of the Tashkent Medical Academy. Bacteriological studies of wound discharge and biopsy material were carried out. We studied the material of purulent-inflammatory diseases of soft tissues.

Results: Wound-sounding through a dioxidine solution is most effective against gram-negative bacteria, and ultrasonic cavitation in combination with iodopyrone is most effective against gram-positive microorganisms. Treatment of purulent wounds with low-frequency ultrasound through a mixture of iodopyrone solution and ascorbic acid is effective against gram-positive and gram-negative microbes. Argon plasma flows have a high bactericidal effect mainly on gram-negative bacteria.

Conclusion: The obtained data substantiate the need to choose a physical method of treatment of purulent wounds depending on the species composition of the wound microflora.

Introduction

At present, research on the problem of wounds and wound infection is being carried out intensively, as questions about the structure and treatment of infection in wounds are as relevant as they were many years ago [1-9].

Thus, it is known that patients with purulent processes of soft tissues make up a third of surgical patients.

The main causative agents of these diseases are *Staphylococcus aureus*, *Enterococci*, *Escherichia*, *Klebsiella*, *Enterobacter*, *Pseudomonas aeruginosa*, and some other non-fermenting gram-negative bacteria. Often in the purulent focus, they are present in associations with obligate non-spore-forming microorganisms [10-19].

Such a variety of inflammatory pathogens with their different sensitivity to antibacterial drugs determines the need to develop more effective means and methods of influencing the purulent microflora of wounds. The use of physical treatment factors, in particular, low-frequency ultrasound and ionized plasma flows, should be considered promising for solving this problem.

The accumulated experience of clinical and experimental studies has revealed a pronounced bactericidal, phonophoresis, analgesic, necrolytic and stimulating reparative effect of ultrasound. But even now, the interest of surgeons in ultrasound treatment of wounds as a simple and affordable method of postoperative debridement of a purulent wound does not weaken. Of considerable interest are the enhancement of the antimicrobial properties of drugs and the change in the biological properties of the pathogens of purulent-inflammatory processes of soft tissues in the sounding of wounds through solutions of anionic (iodopyrone) and cationic (dioxide) antiseptics [20-27].

The results of studies obtained in recent years indicate a pronounced antimicrobial effect of plasma flows of inert gases and the absence of a negative effect on the body as a whole with its repeated local application. However, additional clinical and experimental studies are needed to study the antimicrobial activity of argon plasma flows, since there is contradictory information in the literature about the predominant effect of the plasma jet of argon on either gram-positive or gram-negative microflora.

It is important to compare the antibacterial effect of these completely different physical methods of antisepsis in terms of a differentiated approach to their use in the treatment of purulent wounds depending on the microflora of the purulent focus.

Our study aimed to compare the impact of various physical factors on surgical infection depending on its species composition and to substantiate their use in the postoperative treatment of purulent wounds.

Materials and methods

The paper presents the results of a bacteriological study of wound biopsies taken from 355 patients with purulent-inflammatory processes of soft tissues of various localization and genesis. 34.93% were patients with acute purulent lactation mastitis, 34.08% with abscesses and phlegmons, and 30.99% with suppurating postoperative wounds. 2980 strains of aerobic and facultative-anaerobic bacteria were isolated and studied from the clinical material.

In the first 6 hours, all hospitalized patients had their purulent focus opened under general or local anaesthesia. After mechanical cleaning of the wound from pus and necrotic masses, the material was taken from its deep parts for bacteriological examination.

In the postoperative period, wounds were treated under bandages with various drugs, or wound surfaces were additionally treated with a plasma jet of argon or low-frequency ultrasound.

In order to determine the efficacy of the method of postoperative treatment of purulent wounds, all patients were divided into 7 groups: group I consisted of 40 patients who were treated for purulent wounds using hydrophilic ointment dressings (control group); in group II - 40 patients, postoperative wound sanitation was carried out with a 1% iodopyrone solution (control group); Group III included 40 people who were irrigated with a 1% dioxidine solution after surgical debridement of the wound (control group); Group IV consisted of 137 patients who underwent ultrasound treatment of wounds through a 1% iodopyrone solution; group V - 18 patients, the intermediate medium for wound sounding was a mixture of 1% iodopyrone solution and 5% ascorbic acid solution; Group VI consisted of 40 patients who were treated with a 1% dioxidine solution as an acoustic medium during ultrasound treatment of wounds; in group VII - 40 people, postoperative treatment of wound surfaces was carried out with plasma flows of argon.

In all groups, patients in the postoperative period underwent antibacterial, detoxification therapy, correction of acid-base balance, and replenishment of protein and vitamin balance.

Wound biopsy sampling and microbiological examination were repeated on the 3rd and 5th days after surgery before and after the treatment session.

During the bacteriological examination, the following were studied: the number (of colony-forming units per 1 gram of wound tissue); species composition of microflora; and changes in the biological properties of clinical strains of microorganisms. The species composition of the microflora was studied according to generally accepted methods, using Bergi's nomenclature.

In the course of the work, an ultrasonic generator of the URSK-7N-18 type with a set of acoustic units was used. 1% iodopyrone solution, 1% dioxidine solution, and a mixture of 1% iodopyrone solution and 5% ascorbic acid solution were used as intermediates.

The source of plasma flows was the AKS-V unit. Treatment of wound surfaces was carried out at a current of 20 A, an arc voltage of 30 V, an overpressure of gas of 0.2 - 0.25 kg/cm^2, and a cooling water flow rate of 3 l/min. The distance from the plasma torch nozzle to the tissue was 20 cm, and the exposure was 15 seconds—every field of light.

The operating modes of the plasma torch and the ultrasonic generator corresponded to the modes of impact on wound surfaces. In the bacterial cultures that grew a day later, the biological properties were checked according to generally accepted methods.

Processing and analysis of the obtained data was carried out using the SAS 6.11 statistical software package (SAS Institute, Heidelberg, Germany). The following parameters were used: percentages, arithmetic mean, standard error of the arithmetic mean, reliability of differences, confidence interval, exact Fisher test and Cochran-Hermitage test.

Results

After surgical debridement of wounds, the amount of Colony-Forming Units (CFU) in 1 g of wound tissue of patients of different observation groups was approximately the same and amounted to 10^7-10^8 CFU/g. After the first exposure to wound surfaces with low-frequency ultrasound through a solution of iodopyrone or a mixture of iodopyrone and ascorbic acid, the amount of CFU decreased by 3 orders of magnitude (1000 times, $p < 0.05$), and in combination with dioxidine - by 2 orders of magnitude (100 times, $p < 0.05$).

After the second session of wound sounding, the greatest bactericidal effect was achieved after the effect on the wounds through a mixture of iodopyrone with ascorbic acid or only through iodopyrone. The number of CFU/g of wound tissue decreased by 5 orders of magnitude compared to baseline ($p < 0.05$). The second exposure of wounds to ultrasound in combination with dioxidine was slightly lower, which led to a decrease in CFU/g of wound tissue by 4 orders of magnitude (10,000-fold, $p < 0.05$) compared to baseline data.

After three sessions of wound treatment with low-frequency ultrasound through iodopyrone solution or a mixture of iodopyrone and ascorbic acid, the CFU/g amount decreased by 7 orders of magnitude ($p < 0.05$) and amounted to lg 1.21 ± 0.10 and lg 0.65 ± 0.15, respectively. After three sessions of wound sounding through a dioxidine solution, microbial contamination decreased by 6 orders of magnitude ($p < 0.05$) and amounted to lg l 12 ± 0.17 compared to baseline (lg 7.02 ± 0.21).

As a result of three sessions of treatment of wound surfaces with plasma flows of argon, the number of CFU/g of tissue also decreased by 6 orders of magnitude ($p < 0.05$) (from lg 7.77 ± 0.21 to lg 1.81 ± 0.20).

The main causative agents of purulent-inflammatory processes in group I patients who were treated under dressings with hydrophilic ointments were *S. aureus* (27.12%) and *E. coli* (16.95%). Within five days of wound treatment with this method, the frequency of isolation of microorganisms from wound biopsies decreased by 23.73%; Moreover, gram-positive and gram-negative flora are the same (by 13.55% and 10.19%, respectively).

In groups II and III of clinical observations, *Staphylococci*, and *Enterobacteriaceae* were also the main causative agents of wound infection. As a result of postoperative local treatment of wounds with iodopyrone solution, the frequency of bacterial isolation from wounds decreased by 34.78%, and dioxidine solution by 25.0%. In the first case, the seeding rate of gram-positive bacteria decreased by 27.54% ($p < 0.05$), and gram-negative bacteria by 7.24% ($p > 0.05$). In the third group of clinical observations, the isolation of gram-positive microflora decreased by 7.59% ($p > 0.05$), and gram-negative microflora by 17.31% ($p < 0.05$).

Before the start of treatment with low-frequency ultrasound in group IV, the causative agents of purulent-inflammatory processes were *Staphylococci* in 46.73% of cases, *Enterobacteriaceae* in 31.01%, *Streptococci* in 9.81%, and non-fermenting literate bacteria in 10.45%.

After three sessions of wound treatment with ultrasound in combination with iodopyrone, the frequency of excretion of gram-positive microflora decreased by 29.08% and gram-negative microflora by 16.67% compared to the initial data ($p < 0.05$). Moreover, *Staphylococci* were isolated by 22.87% less ($p < 0.05$), *E. coli* - by 4.9% less, *Streptococci* - by 6.22%, and non-fermenting gram-negative bacteria - by 6.53% ($p > 0.05$).

In group V patients, wound sounding was carried out through a mixture of 1% iodopyrone solution and 5% ascorbic acid solution. At the same time, the antibacterial properties of the combined effect of ultrasound and iodopyrone were significantly enhanced. The frequency of isolation of bacteria from wound biopsies after three sessions of treatment with this method decreased by 53.57%: by 32.56% of gram-positive microflora and by 24.99% of gram-negative microflora ($p < 0.05$).

Treatment of wound surfaces with low-frequency ultrasound through a 1% dioxidine solution after three voicing sessions led to a decrease in the frequency of bacterial isolation from wound biopsies by 32.14%. At the same time, gram-positive microorganisms were excreted 7.14% less ($p > 0.05$), and gram-negative microorganisms - by 24.99% ($p < 0.05$). The obtained data show a predominant bactericidal effect of low-frequency ultrasound in combination with dioxidine on gram-negative bacteria.

The defocused plasma flow of argon in the proposed mode had a more effective effect on gram-negative bacteria than on gram-positive ones. Thus, the frequency of excretion of *Staphylococci* and *Streptococci* from the wounds of patients after the third treatment with plasma flows of argon decreased by 22.57%, *Enterobacteriaceae* - by 32.26%, and non-fermenting gram-negative bacteria - by 4.84%.

During bacteriological control of the efficacy of local treatment of purulent-inflammatory processes of soft tissues, 1122 strains of *S. aureus* were isolated from wound biopsies in 355 patients. In all isolated cultures of *Staphylococcus aureus*, the ability to produce plasma coagulase, lecithinase and hemolysin, as well as to ferment mannitol under anaerobic conditions, was studied.

It was noted that when comparing the frequency of isolation of *S. aureus* strains before and after treatment of wound surfaces during five days of postoperative treatment with hydrophilic ointments, iodopyrone, or dioxidine solution, there were no statistically significant differences in the results for all studied parameters ($p > 0.05$).

115 strains of *S. aureus* were isolated from wound biopsies of group IV patients after surgery. Of these, 109 strains (94.78%) caused coagulation of blood plasma, 113 strains (98.26%) lysed erythrocytes and fermented mannitol, 111 strains (96.52%) had lecithinase activity. After the third

sounding of wounds through iodopyrone solution, 66 strains of *Staphylococcus aureus* were isolated from biopsy samples. At the same time, the frequency of isolation of plasma-coagulating *Staphylococci* decreased by 20% ($p < 0.001$), those producing hemolysin - by 32% ($p < 0.01$), lecithinase - by 16% ($p = 0.001$), those with DNA ase - by 5% ($p = 0.045$), fermenting mannitol - by 24% ($p < 0.001$).

In the process of exposure to wounds with ultrasound through a mixture of iodopyrone and ascorbic acid (group V) on the fifth day of the postoperative period, the frequency of isolation of *S. aureus* strains with typical enzymatic properties also decreased markedly. Thus, the number of strains with plasma-coagulating and hemolytic activity decreased by 67% ($p < 0.05$ and $p > 0.001$, respectively). The frequency of isolation of *S. aureus* with a lecithinase trait decreased by 22% ($p < 0.01$), with DNA-ase capacity by 19% ($p < 0.05$), and fermenting mannitol by 52% ($p < 0.01$).

The addition of ascorbic acid to the iodopyrone solution during wound sounding led to a significant decrease in the enzymatic activity of *Staphylococcus aureus*. For example, after the third session of wound treatment with ultrasound in combination with iodopyrone and ascorbic acid, the frequency of isolation of strains of *S. aureus* that produce hemolysin and ferment mannitol was lower than after ultrasound in combination with iodopyrone ($p = 0.034$ and $p = 0.022$, respectively).

In 710 strains of *E. coli* isolated from the wounds of 355 patients before and after each session of local treatment of purulent-inflammatory processes of soft tissues, biochemical properties, and mobility were studied.

Under the influence of low-frequency ultrasound through a dioxidine solution, the frequency of isolation of *Escherichia coli* strains from wound biopsies that changed enzymatic activity and lost mobility ($p < 0.01$ and $p < 0.05$, respectively) increased. In particular, the seeding frequency of *E. coli* strains unable to ferment glucose and decarboxylate lysine and ornithine increased by 52.3% ($p = 0.02$), fermentation of maltose and mannitol by 40% ($p = 0.03$), glucose by 80% ($p < 0.001$).

Exposure to wound surfaces with ultrasound in combination with iodopyrone and ascorbic acid caused a 66.7% decrease in the frequency of isolation of *E. coli* strains fermenting glucose, lactose, maltose, and mannitol ($p < 0.05$), and a 66.7% increase in the number of non-motile strains of *Escherichia coli* ($p = 0.016$).

The modulating effect of the plasma flow of argon on the biological properties of clinical strains of *E. coli* isolated from wounds after appropriate treatment compared to the effect of ultrasound was insignificant and in all cases almost the same ($p > 0.05$ according to all biochemical tests).

Thus, the most pronounced modulating effect on the biological properties of *E. coli* strains isolated from wounds is low-frequency ultrasound in combination with dioxidine, as well as in combination with a mixture of iodopyrone and ascorbic acid.

Analysis of the results of *in vitro* studies showed that the viability of *S. aureus* under the influence of chemical and physical factors decreased compared to the survival of *Staphylococcus aureus* in a control tube with saline. The greatest antibacterial effect on *Staphylococcus aureus* was exerted by the combined effect of low-frequency ultrasound with a mixture of iodopyrone solution and ascorbic acid. At the same time, lg 2.55 ± 0.02 and lg 3.67 ± 0.03 CFU, respectively ($p > 0.05$) survived. Sounding microbes through a 1% dioxidine solution caused a pronounced bactericidal effect on *Staphylococcus aureus*, but it turned out to be weaker than after treatment of the culture with low-frequency ultrasound in combination with iodopyrone ($p < 0.05$).

When analyzing the results of the influence of physical factors on the enzymatic properties of *S. aureus*, it was revealed that ultrasonic cavitation in combination with a mixture of iodopyrone and ascorbic acid solution had the greatest effect on them. At the same time, out of 30 cases, compared to the results of cultures in the control experiment (saline), 21 strains (70.0%) lost plasma coagulase, 18 strains (60.0%)-lecithinase, 20 (66.67%) -hemolysin and 18 strains (60.0%) did not ferment mannitol under anaerobic conditions ($p < 0.001$).

After treatment of *S. aureus* culture with ultrasound and iodopyrone solution, these indicators are slightly lower compared to the previous group. For example, 14 strains of staphylococcus (46.67%) became coagulase-negative, 12 strains (40.0%) did not produce lecithinase, 15 strains (50.0%) did not produce hemolysin, 11 strains (36.67%) ($p > 0.05$) did not ferment mannitol, 9 strains (30%) did not ferment mannitol ($p < 0.05$).

The sound of *S. aureus* strains through a dioxidine solution led to the loss of the above-mentioned enzymes in 1 - 3 strains (3.33 - 10.0%), which is much less compared to the treatment of these strains with an iodopyrone solution or a mixture of iodopyrone and ascorbic acid ($p < 0.001$).

Plasma flows of argon had a slight effect on the enzymatic activity of *S. aureus*: 2 strains (6.67%) lost plasma coagulase and lecithinase and 3 strains (10.0%) did not secrete hemolysin ($p > 0.05$). DNA-ase activity and the ability to ferment mannitol did not change.

Analysis of the results of the studies revealed a high bactericidal effect of argon plasma flows on control strains of *E. coli* compared to the results of cultures in other experiments.

The greatest modifying effect on the enzymatic activity and mobility of control strains of *E. coli* was exerted by low-frequency ultrasound in combination with dioxidine. After this treatment, 8 strains (26.67%) of *Escherichia coli* lost the ability to ferment glucose, 10 strains (33.33%) lost their ability to ferment lactose, and 9 strains (30.0%) became immobile. These results are statistically significant to the results of cultures of the initial suspension of *E. coli*, as well as after treatment with a dioxidine solution and low-frequency ultrasound through iodopyrone ($p < 0.001$). The addition of ascorbic acid strains to iodopyrone contributed to the transformation of the initial biochemically active, mobile strains into glucose- and lactose-negative (13.34% each), and 16.67% (5 strains) lost their mobility under these conditions ($p < 0.05$). Plasma flows of argon had a weak modifying effect on the enzymatic activity and motility of Escherichia coli.

Thus, the greatest bactericidal effect on control strains of *E. coli* is exerted by plasma flows of argon. The bactericidality of low-frequency ultrasound in combination with iodopyrone solution was an order of magnitude lower compared to the effect of a plasma jet of argon ($p < 0.05$). The modulating effect on the enzymatic properties and motility of *E. coli* was significant after sounding through a dioxidine solution. Plasma flows of argon and ultrasound in combination with iodopyrone did not affect the biological properties of *Escherichia coli*.

Analysis of the survival rate of control strains of *K. pneumoniae* depending on the effect of various factors on them showed that plasma flows of argon had the greatest bactericidal effect.

Compared to the viability of *Klebsiella* in saline, the bacteria after treatment with the plasma jet were seeded in an amount 4 orders of magnitude less, which amounted to lg 2.50 ± 0.01 CFU/ml ($p < 0.05$). A slightly smaller antibacterial effect was obtained after exposure to *Klebsiella* with low-frequency ultrasound through a dioxidine solution: lg 3.12 ± 0.06 CFU/ml ($p < 0.05$) survived. Approximately the same result was obtained after exposure to ultrasound in combination with iodopyrone and ascorbic acid: the amount of CFU/ml was Ig 3.16 ± 0.07 ($p > 0.05$ compared to the effect of plasma flows).

Treatment of control strains of *K. pneumoniae* with ultrasound through iodopyrone solution reduced the amount of CFU/mL by three orders of magnitude compared to baseline data ($p < 0.05$), but this effect was weaker than after ultrasound in combination with dioxidine or in combination with a mixture of iodopyrone solution and ascorbic acid, and especially after irradiation with argon plasma ($p < 0.05$).

When studying the effect of physical factors on the enzymatic activity of *K. pneumoniae in vitro*, it was found that the largest number of *Klebsiella* strains with altered enzymatic properties, as well as *in vivo*, was obtained after exposure of bacteria to low-frequency ultrasound through a dioxidine solution. At the same time, 36.67% of the strains lost the ability to ferment glucose, 26.67% of lactose and 10.00% of mannitol, did not utilize sodium citrate of 10.00% of strains and did not hydrolyze urea of 20% of *Klebsiella* ($p < 0.05$).

Changes in the biochemical activity of *Klebsiella* after exposure to low-frequency ultrasound through a mixture of iodopyrone and ascorbic acid were somewhat weaker ($p < 0.05$), and plasma flows of argon and ultrasound in combination with iodopyrone had practically no effect on the enzymatic properties of *K. pneumoniae*.

Thus, the results of our research indicate that in the treatment of purulent wounds by physical methods, their effectiveness largely depends on the species composition of the wound microflora, and this must be taken into account in order to achieve an early clinical effect.

Discussion

Analysis of the obtained data allows us to talk about a pronounced bactericidal effect of all physical factors studied in the work on the control strains of *S. aureus*. However, the greatest antimicrobial activity against staphylococci is shown by low-frequency ultrasound in combination with a mixture of iodopyrone and ascorbic acid. At the same time, the enzymatic properties of *S. aureus* change with a high degree of reliability.

The analysis of the data obtained showed that argon plasma flows and low-frequency ultrasound with different conductive media caused a pronounced bactericidal effect. However, the most significant antimicrobial effect on the microflora of purulent wounds was exerted by low-frequency ultrasound in combination with a mixture of iodopyrone and ascorbic acid [1-9].

Analysis of the obtained data allows us to conclude that low-frequency ultrasound in combination with 1% iodopyrone solution has a more effective effect on gram-positive wound microflora than on gram-negative ones.

The results obtained indicate a high bactericidal value of low-frequency ultrasound in combination with iodopyrone and ascorbic acid against both gram-negative and gram-positive microorganisms.

Treatment of wound surfaces with plasma flows of argon or low-frequency ultrasound through dioxidine revealed no statistically significant changes in the enzymatic activity of *S. aureus*.

We found that as a result of exposure to wound surfaces with hydrophilic ointments, iodopyrone solution, argon plasma flows, and low-frequency ultrasound in combination with iodopyrone, no statistically significant changes in biochemical properties and loss of mobility of *Escherichia coli* strains were observed. After treatment of wounds with a dioxidine solution, the frequency of isolation of *E. coli* strains fermenting mannitol and maltose ($p = 0.025$), and decarboxylating lysine ($p = 0.034$) decreased compared to the initial data.

If we compare the modulating effect of ultrasound in different conductive media on the biochemical properties and mobility of clinical strains of *E. coli*, the effect of ultrasonic cavitation through a dioxidine solution was predominant compared to wound sounding through iodopyrone, but comparable in many indicators with the effectiveness of the same effect on the wound by ultrasound in combination with a mixture of iodopyrone and ascorbic acid.

The analysis of the data obtained in our work allows us to conclude that the bactericidal effect of low-frequency ultrasound *in vivo* and *in vitro* depends not only on the chemical nature of the conductive medium but also on the species composition of the wound microflora. This is confirmed by the results of the study of the enzymatic activity of bacteria under similar conditions.

As for the use of plasma flows of argon for local treatment of wounds, its bactericidal effect has been established mainly on gram-negative microflora, but no significant changes in the biochemical properties of bacteria preserved after exposure to them *in vivo* and *in vitro* were found in our work.

Conclusion

The antimicrobial effect of physical factors in the postoperative treatment of purulent-inflammatory processes of soft tissues depends not only on the physical method of impact on the wound but also on the species composition of the microflora. Low-frequency ultrasound in combination with dioxidine effectively affects gram-negative wound microflora (*E. coli*, *K. pneumoniae*). Clinical strains of gram-positive bacteria, in particular *S. aureus*, are sensitive to the action of low-frequency ultrasound through iodopyrone solution. Ultrasonic cavitation through a mixture of iodopyrone and ascorbic acid has an antimicrobial effect on both gram-positive and gram-negative microorganisms. *In vitro* testing of control strains of *S. aureus*, *K. pneumoniae*, and *E. coli* in combination with 1% dioxidine solution, or 1% iodopyrone solution, or a mixture of 1% iodopyrone solution and 5% ascorbic acid solution, confirms the results of studies of clinical strains of wound infection pathogens. Plasma flows of argon in the treatment of purulent wounds provide a pronounced antibacterial effect mainly on gram-negative bacteria, which is confirmed by *in vitro* studies.

With a differentiated approach to the use of physical factors in the postoperative treatment of purulent wound infection, microbiological monitoring of biopsy material is advisable. Ultrasound debridement of purulent wounds in combination with dioxidine solution is recommended for wound infection caused by gram-negative bacteria, and in combination with iodopyrone solution for gram-positive wound infection. In cases where the purulent inflammatory process of soft tissues is caused by a mixed infection, it is advisable to treat wounds with low-frequency ultrasound through a mixture of iodopyrone solution and ascorbic acid. The use of argon plasma flows in the treatment of purulent wound infection is recommended when gram-negative bacteria predominate in the wound.

Ethics approval and consent to participate: All patients gave written informed consent to participate in the study.

Consent for publication: The study is valid and recognition by the organization is not required. The author agrees to open publication.

Availability of data and material: Available

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