https://doi.org/10.34883/PI.2024.13.4.026
UDC 616.379-008.64+617.586.1-002.45(617.582-089.873+617.578-089.873)

Khamdamov B.[1], Davlatov S.[1]✉, Yanchenko S.[1], Rakhmanov K.[2]
[1] Bukhara State Medical Institute named after Abu Ali ibn Sino, Bukhara, Uzbekistan
[2] Samarkand State Medical University, Samarkand, Uzbekistan

Improvement of Surgical Treatment of Patients with Purulent-Necrotic Complications of Diabetic Foot Syndrome

Conflict of interest: nothing to declare.
Authors' contribution: Khamdamov B. – concept and design of the study, analysis of materials and results, writing an article; Davlatov S. – conducting research, collecting, analyzing materials and results, writing an article; Yanchenko S. – participation in the analysis of materials and results; Rakhmanov K. – conducting research, participating in the analysis of materials and results.
Funding: the study does not have sponsorship.
The article is published in author's edition.

Submitted: 14.08.2024
Accepted: 15.11.2024
Contacts: sammi-xirurgiya@yandex.com

Abstract

Introduction. Diabetic foot infections are an important problem for diabetic patients today because they impair patients' quality of life, increase the frequency of hospitalisations and are costly to treat. Although diabetes itself requires long-term treatment, studies show that patients with diabetic foot are hospitalised twice as often as diabetic patients who do not have foot problems. The American Diabetes Association states that despite developed treatments and educational programmes, 60–70% of all diabetic patients experience lower limb amputations due to diabetic foot.
Purpose. Improving the results of complex surgical treatment of patients with purulent-necrotic complications of diabetic foot syndrome by optimising the methods of determining the proper level of amputation of the affected lower limb.
Materials and methods. The paper analyses the results of complex examination and surgical treatment of 312 patients with purulent-necrotic complications of diabetic foot syndrome who were on inpatient treatment in the department of purulent surgery of Bukhara Regional Multidisciplinary Medical Centre in the period from 2017 to 2023.
Results. A comparative analysis of purulent-necrotic complications that were the reason for performing lower limb reamputations at a higher level showed that while purulent-necrotic complications from the amputation stump of the fingers in the comparison group accounted for 8.8%, in the main group these complications were observed in 3.9% of patients. Progression of wound infection at the level of the foot in the comparison group was 6.3%, while in the main group of patients 3.3% of cases. Progression of wound infection on the side of the amputation stump of the tibia in the comparison group was observed in 3.9% of patients, while these indicators in the main group of patients made up 3.3% of cases. Progression of wound infection on the side of the thigh amputation stump in the comparison group was 1.9%, in the main group such complications were not observed.

Conclusion. The application of the developed algorithm allows to change radically the stratification of amputations at one or another level, based on the implementation of the principles of routine methods of determining the expected level of limb truncation towards optimisation, allowing to minimise the number of unjustified high amputations from 23.9% to 10.5% and lethal outcomes from 11.95% to 3.92% of cases respectively.
Keywords: diabetic foot syndrome, systemic inflammatory response syndrome, amputation, electromagnetic photon matrix emitter, fine-needle puncture express histology, lactoferrin

Хамдамов Б.З.[1], Давлатов С.С.[1]✉, Янченко С.В.[1], Рахманов К.Э.[2]
[1] Бухарский государственный медицинский институт имени Абу Али ибн Сино, Бухара, Узбекистан
[2] Самаркандский государственный медицинский университет, Самарканд, Узбекистан

Совершенствование хирургического лечения пациентов с гнойно-некротическими осложнениями синдрома диабетической стопы

Конфликт интересов: не заявлен.
Вклад авторов: Хамдамов Б.З. – концепция и дизайн исследования, анализ материалов и результатов, написание статьи; Давлатов С.С. – проведение исследования, сбор, анализ материалов и результатов, написание статьи; Янченко С.В. – участие в анализе материалов и результатов; Рахманов К.Э. – проведение исследования, участие в анализе материалов и результатов.
Финансирование: исследование не имело спонсорской поддержки.
Статья опубликована в авторской редакции.

Подана: 14.08.2024
Принята: 15.11.2024
Контакты: sammi-xirurgiya@yandex.com

Резюме

Введение. Инфекции при синдроме диабетической стопы сегодня являются серьезной проблемой для пациентов с диабетом, поскольку ухудшают качество жизни, увеличивают частоту госпитализаций и требуют высоких затрат на лечение. Диабет в любом случае требует длительного лечения, вместе с тем исследования показывают, что пациенты с диабетической стопой госпитализируются в два раза чаще, чем пациенты с диабетом, у которых нет проблем со стопами. Американская диабетическая ассоциация отмечает, что, несмотря на разработанные методы лечения и образовательные программы, у 60–70% пациентов с диабетом возникает необходимость в ампутации нижних конечностей из-за синдрома диабетической стопы.
Цель. Улучшение результатов комплексного хирургического лечения пациентов с гнойно-некротическими осложнениями синдрома диабетической стопы путем оптимизации методов определения должного уровня ампутации пораженной нижней конечности.
Материалы и методы. В работе проанализированы результаты комплексного обследования и хирургического лечения 312 пациентов с гнойно-некротическими

осложнениями синдрома диабетической стопы, находившихся на стационарном лечении в отделении гнойной хирургии Бухарского областного многопрофильного медицинского центра в период с 2017 по 2023 г.

Результаты. Сравнительный анализ гнойно-некротических осложнений, послуживших причиной выполнения реампутаций нижних конечностей на более высоком уровне, показал, что в группе сравнения гнойно-некротические осложнения со стороны ампутационной культи пальцев наблюдались в 8,8% случаев, а в основной группе – в 3,9%. Прогрессирование раневой инфекции на уровне стопы у пациентов группы сравнения выявлено в 6,3% случаев, в основной группе – в 3,3%. Прогрессирование раневой инфекции со стороны ампутационной культи голени в группе сравнения наблюдалось у 3,9% пациентов, в то время как в основной группе эти показатели составили 3,3%. Прогрессирование раневой инфекции со стороны ампутационной культи бедра у пациентов группы сравнения наблюдалось в 1,9% случаев, у пациентов основной группы таких осложнений не было.

Заключение. Применение разработанного алгоритма, основанного на реализации принципов рутинных методов определения предполагаемого уровня усечения конечности в сторону оптимизации, позволяет коренным образом изменить стратификацию выполнения ампутаций на том или ином уровне и минимизировать количество необоснованных высоких ампутаций конечности с 23,9% до 10,5%, а летальных исходов с 11,95% до 3,92%.

Ключевые слова: синдром диабетической стопы, синдром системного воспалительного ответа, ампутация, электромагнитный фотонно-матричный излучатель, тонкоигольная пункционная экспресс-гистология, лактоферрин

■ INTRODUCTION

Diabetic foot infections are an important problem for diabetic patients today because they impair patients' quality of life, increase the frequency of hospitalisations and are costly to treat. Although diabetes itself requires long-term treatment, studies show that patients with diabetic foot are hospitalised twice as often as diabetic patients who do not have foot problems. The American Diabetes Association (ADA) states that despite developed treatments and educational programmes, 60–70% of all diabetic patients experience lower limb amputations due to diabetic foot [1–4].

The presence of signs of lower limb ischaemia in diabetic foot syndrome indicates a poor outcome of the purulent-necrotic process in the limb. At the same time, according to the transatlantic consensus, within the first year from the moment of the first establishment of signs of critical lower limb ischaemia it is resolved in only 25% of patients, more than 30% of patients surgeons have to perform high amputations of lower limbs for vital indications [5–8]. According to the literature data, purulent-necrotic complications from the side of the amputation stump of the limb make up from 12 to 23% of cases [4, 9–11]. At the same time, the more distal the level of amputation, the higher the percentage of purulent-necrotic complications on the side of the amputation stump. Therefore, most surgeons try to perform high amputations at the thigh level, since the higher the level of limb truncation, the higher the proportion of primary tension of the amputation stump [12].

In the world practice there are scientific studies aimed at developing new approaches to determining the optimal level of lower limb truncation in severe purulent-necrotic complications of DFS syndrome, which could not only save patients' lives, but also create favourable conditions for healing of the amputation stump and early rehabilitation of this category of patients [13–16].

It is of particular importance to assess the viability of the lower limb tissues at the level of which amputation is planned to be performed in order to prevent purulent-necrotic complications from the amputation stump, which in most cases leads to reamputation in the best case, and in the worst case, to the development of systemic inflammatory response syndrome, as well as multi-organ dysfunction with lethal outcome.

■ PURPOSE OF THE STUDY

Improving the results of complex surgical treatment of patients with purulent-necrotic complications of diabetic foot syndrome by optimising the methods of determining the proper level of amputation of the affected lower limb.

■ MATERIALS AND METHODS

The results of complex examination and surgical treatment of 312 patients with purulent-necrotic complications of DFS who were hospitalised in the department of purulent surgery of Bukhara Regional Multidisciplinary Medical Centre in the period from 2017 to 2023 were analysed. All patients had different signs of severity of systemic inflammatory response syndrome. In accordance with the objectives of the study and depending on the complex treatment and methods of determining the level of amputation, the patients were conditionally divided into two groups. The first (2017–2020) group consisted of 159 (50.96%) patients, for whom the complex of surgical treatment consisted of amputations at different levels of the lower extremities for vital indications, by traditional methods before surgical preparation. The level of lower limb truncation in this group of patients was determined by routine methods: objective examination (local status), dopplerography, thermometry, determination of tissue oxygen tension, determination of ankle-shoulder index (ASI), angiography. The second, main group (2021–2023) consisted of 153 (49.04%) patients who underwent lower limb amputations at different levels for vital indications. The complex of preoperative administration of patients of this group additionally included indirect electrochemical plasma detoxification, local treatment of wound infection was carried out by means of sanation with ointments on polyethylene glycol base – Oflomelid. In order to improve blood supply of the affected limb and to create conditions for implementation of the strategy of more economical methods of amputation we used the method of electromagnetic radiation by photon-matrix radiator at the supposed level of limb truncation with duration up to 10 minutes 2 times a day. The duration of sessions was from 1 to 3 days. The optimal level of truncation was determined by fine-needle biopsy with the following express histological method of tissue viability and acute phase protein indices – lactoferrin at the supposed level of limb amputation. Fine-needle puncture was performed using a special needle for soft tissue biopsy (fig. 1).

The prevalence of women was 162 (51.9%), men were 150 (48.1%). The average age of the patients was 58.4±11.2 years. Most of the patients 175 (56.09%) were at the age of highest labour activity (45 to 60 years).

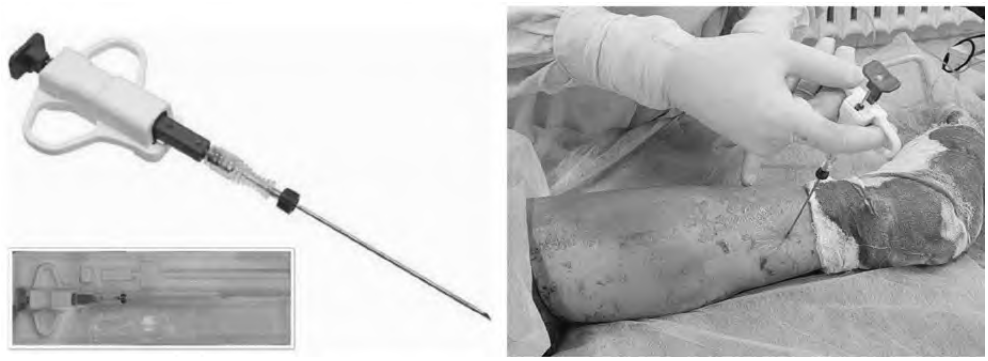

Fig. 1. Soft tissue biopsy needle (Medax, Italy – 14 G × 160 mm)

Diabetic history ranged from newly diagnosed to 10 or more years. In most of the cases observed, the patients had type 2 diabetes mellitus (95.5%). Where mainly medium and severe degrees of severity of the course of diabetes mellitus in the stage of subcompensation and decompensation were observed. In 312 patients examined, the following forms of foot changes were presented: purulent-necrotic phlegmon of the foot – 88; gangrene of the toes (dry and wet) – 126; gangrene of the distal parts of the foot (dry and wet) – 67. Creeping putrefactive phlegmons of the foot, carpal space and tibia – 31. One or more concomitant diseases were revealed in 291 (93.3%) patients.

In both groups the patients underwent: phlegmon dissection, guillotine atypical amputations of the foot and tibia, finger amputations, foot amputations according to Chopar, Sharpe, Lisfranc, high myoplastic amputations at the level of the tibia, amputations at the level of the thigh. Upon admission to the hospital, the surgical stage was performed, if possible, against the background of a complete examination of the patient in combination with an adequate complex of conservative measures. When assessing purulent-necrotic lesions of the limb, we followed the classification proposed by (Wagner F.W., 1981), which is the most used classification of ulcerative lesions of the foot in diabetes depending on the depth of tissue destruction. In assessing critical lower limb ischaemia, we used the classification proposed by the North American Society for Vascular Surgery (SVS), which is easy to use; the SVS Lover Extremity Threatehed Limb Classification System (SVS WIFI), which provides an analysis of the condition of the limb, the risk of major amputation. It is based on the grading of each of the three main pathological processes (wound, ischemia, foot infection – WIFI). A scale from 0 to 3 is proposed, where 0 means none, 1 means mild degree, 2 means moderate degree, 3 means severe degree. Each of the three categories (ulcer, ischaemia, foot infection) has 4 degrees of severity, which theoretically gives 64 possible clinical combinations. Indications for amputations at different levels of the lower limbs were the data of local status, radiography of the affected lower limb bones, Doppler ultrasonography, soft tissue oxygen perfusion, ankle-shoulder index (ASI), and angiographic examination if indicated. Indications for emergency surgical interventions were, first of all, wet gangrene of fingers and feet, phlegmon of the foot, as well as phlegmon of the foot with inflammation transition to the lower leg with severe intoxication, creating a threat to the patient's life. As a rule, it was performed in order to

save his life. Indications for urgent surgical interventions were: purulent-necrotic wounds without adequate drainage; deep abscesses of the foot; distant septic metastatic foci; newly formed abscesses and poorly drained purulent congestion. Patients in the comparison group underwent a complex of therapeutic measures, including surgical intervention, antibacterial therapy, infusion, detoxification therapy, drugs improving microcirculation, correction of glycaemia level and symptomatic treatment of concomitant diseases. Topical treatment was carried out in the traditional way (ointments on water-soluble polyethylene glycol base Oflomelid).

The patients in the comparison group were preoperatively prepared and managed in the postoperative period according to the traditional scheme.

In addition to the traditional methods of treatment, the patients of the main group were treated with electromagnetic radiation by photon matrix radiator "Barva-Flex" in the area of the proposed truncation. In order to actively affect endotoxaemia, correction of oxygen homeostasis disorders and to obtain immunomodulatory effect in the treatment plan plasmapheresis (PP) combined with indirect electrochemical oxygenation (IECO) of plasma with sodium hypochlorite with additional ozonation and subsequent reinfusion of detoxified plasma was added. The characteristics of the necrosis focus: its localisation, volume and activity, as well as the state of microcirculation and collateral blood flow in the limb were of fundamental importance for the choice of the level and nature of the sanitising operation.

Laboratory methods of investigation were applied to all patients included in the study. All patients underwent diagnostic procedures to make a diagnosis and determine the severity of the limb lesion. General clinical examination was performed, local and widespread process was differentiated. Laboratory diagnostics included: general blood and urine tests; investigation of glycemia level and glycemic profile, biochemical studies, bacteriological study of wound content.

In 159 patients of the comparison group the choice of the level of lower limb truncation was determined on the basis of "traditional" criteria of tissue viability, and in 153 patients of the main group the assessment of soft tissue viability and the level of lactoferrin activity was of decisive importance when choosing the level of truncation.

In order to determine the level of amputation, we have developed and introduced into clinical practice a method for detecting the viability of soft tissues where amputation of the lower extremities is supposed to be performed. When determining the level of amputation, in addition to routine examination methods (LPI, transcutaneous oximetry, Dopplerography, angiography), we performed a fine needle puncture at the site of the alleged amputation with the taking of biopsy material of the underlying soft tissues (muscles) for express histological examination to determine their viability. Fine needle punctures with biopsy were performed at the assumed level of limb truncation, also 3 cm and 5 cm above this level. The viability of soft tissues (muscles) was determined by the following histological signs: leukocyte infiltration – the presence of neutrophil granulocytes in muscle tissue outside the vascular bed; karyopycnosis – wrinkling of the cell nucleus of myocytes as the initial stage of necrobiotic changes; karyolysis – the process of complete destruction of the cell nucleus with dystrophic changes in it; cytolysis of myocytes is cell destruction determined by light microscopy; violation of the transverse striation of muscle fibers.

We considered changes in the nucleus and cytoplasm of cells to be microscopic signs of necrosis (fig. 2–5). The nuclei successively undergo wrinkling (karyopycnosis), disintegration into lumps (karyorexis) and lysis (karyolysis).

In the presence of histological signs of necrosis and soft tissue necrosis in all three examined points of the alleged truncation, priority was given to higher amputations. Further, the development of a methodology for determining lactoferrin indicators at the expected amputation level and the analysis of its effectiveness in correlation with the express histological method for determining tissue viability was carried out.

To develop this method and implement it into clinical practice, we performed experimental studies on laboratory animals (12 white mongrel rats of both sexes weighing 200-250 g). Using special equipment for fine needle puncture biopsy under local infiltration anesthesia, 1 g of muscle tissue was taken from the femoral muscle of the hind limbs of the animal. The resulting muscle tissue was added with an isotonic solution in a ratio of 1:1 (1 g / 1.0 ml). The amount of lactoferrin in the prepared material

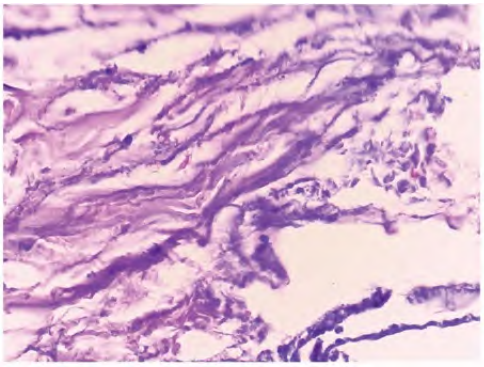

Fig. 2. A bundle of myocytes. Karyorexis (karyolysis). H.-E. 10×3

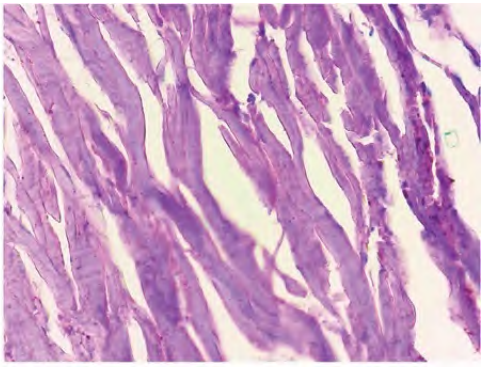

Fig. 3. A bundle of myocytes. Contractural damage. H.-E. 10×4

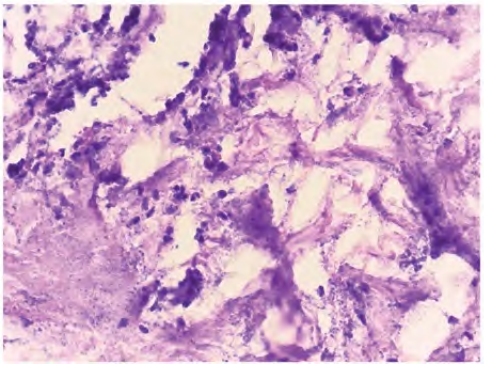

Fig. 4. The area of the musculoskeletal flap. Necrosis and edema. H.-E. 10×3

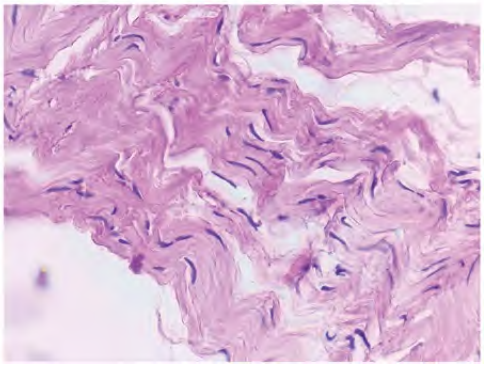

Fig. 5. The normal structure of the muscular layer of the musculoskeletal flap area. H.-E. 10×3

was determined using an enzyme immunoassay analyzer equipped with special reagents for protein substances. Thus, we have developed a method for determining the level of Lactoferrin in the soft tissues of the extremities normally. Which is level 2.91±0.10. Having determined the normal value of lactoferrin levels, we proposed gradations of lactoferrin values in pathological processes observed in the soft tissues of the extremities in the form of necrosis or irreversible conditions. At the same time, a 5-fold increase in lactoferrin levels in muscle tissue was interpreted as a boundary above which all formalized histological signs of soft tissue necrosis were detected (leukocyte infiltration, karyopycnosis, karyolysis, cytolysis of myocytes, violation of transverse striation of muscle fibers). When no more than two formalized signs were detected, there were chances for attempts to restore the viability of soft tissues at the expected level of truncation due to a significant improvement in the microcirculatory bed in this area of the limb. At the same time, in order to improve microcirculation and thereby create favorable conditions for wound healing after amputations at the assumed levels of the lower extremities, we locally applied the method of exposure to electromagnetic photonic matrix radiation. To do this, we used a device – "Barva-Flex" (with an electromagnetic photonic matrix emitter). In patients who, according to indications, it was decided to amputate the lower extremities at one level or another, at which, at the intended level of amputation, the viability criteria were questionable during histological examination of muscle tissue taken by a fine needle puncture method, which usually forces higher amputations of the lower extremities, which ultimately contributes to significant disability in patients with DFS.

As is known, the reasons for the unsatisfactory healing results of an amputation stump are: signs of local ischemia, which are directly related to deep disorders of the local microcirculatory bed. The technique was as follows: we conducted sessions of electromagnetic photonic matrix radiation for 10 minutes 2 times a day (1–3 days) using the Korobov Barva-Flex/SIK apparatus at the estimated amputation level. A patent for an invention by the Intellectual Property Agency of the Republic of Uzbekistan (No. IAP 07441 05/19/2023) was obtained for the method we developed to improve microcirculation of the estimated amputation level.

The use of this method led to a significant improvement in local microcirculation, which was confirmed by improved oxygen saturation of tissues and repeated fine needle biopsies, in which a sharp improvement in signs of tissue viability was noted in the studied material. Thus, the possibility of amputation of the lower extremities at this level was created. This made it possible to reduce the number of lower limb amputations at more proximal levels. The effect is electromagnetic radiation with wavelengths in the range of 600–570 nm on the area of the proposed amputation of the lower limb for 10 minutes per field (fig. 6). The method improves blood circulation, reduces the severity of pain, swelling and discomfort, and changes the color of the skin due to the use of magnetic laser exposure. Design features and technical characteristics of photonic magnetic matrices Korobova A. – Korobova V. "Barva-Flex".

In order to actively influence endotoxemia, correct oxygen homeostasis disorders and to obtain an immunomodulatory effect, plasmapheresis (PF) in combination with indirect electrochemical oxygenation (IECO) of plasma with sodium hypochlorite with additional ozonation and subsequent reinfusion of detoxified plasma was added to the treatment plan for patients of the main group. The criteria for detoxification of exfused plasma, making its reinfusion possible, were determined according to N.M. Fedorovsky (2004).

Fig. 6. Sessions of electromagnetic photonic matrix radiation

■ RESULTS AND DISCUSSION

It should be emphasized that in 12 (7.8%) patients, leukocyte infiltration and karyopycnosis were initially detected during a fine needle biopsy, which meant that the viability of the biopsy material under study was doubtful. As we indicated above, in order to improve local microcirculation and survivability of soft tissues, the method of electromagnetic radiation with a Barva-Flex photonic matrix emitter was used. This method allowed for a significant improvement in microcirculation in the proposed amputation zone, which was proved by a sharp improvement in the viability of soft tissues confirmed by histological and biochemical (lactoferrin level) repeated studies (table 1) after a course of electromagnetic radiation with a Barva-Flex photonic matrix emitter. All taken together, it made it possible not to resort to higher and more crippling amputations, but to perform them at the initially planned level.

Depending on the method of determining the optimal level of amputation of the lower extremities and the fight against endogenous intoxication manifested as a systemic inflammatory response syndrome, all 312 treated patients were conditionally divided into 2 groups compared. At the same time, the main vital signs as well as the local status of the volume of surgical interventions performed were representative. That is, when forming the groups, we observed the principle of representativeness: at the same time,

Table 1
Lactoferrin levels at treatment stages

Indicator	On the day of admission for primary biopsy	Repeated biopsy after a course of electromagnetic radiation
Lactoferrin	15.05±0.57	8.23±0.40

the parameters and volume of the lesion of the lower extremities and concomitant diseases were close to each other (P<0.05). In this regard, we did not consider it advisable to list and analyze in detail the above data, which are set out in previous chapters.

It is known that the clinical picture of the disease is based on the presence of certain symptoms and objective data. At the same time, the effectiveness of any surgical treatment method is evaluated according to the criteria of the outcome of the disease, as well as the development of postoperative complications. A comparative study of the indicators of intoxication of the body, where the dynamics of changes in body temperature of the examined, L – blood, medium-weight molecules (MVM), leukocyte intoxication index (LII), ESR, SaO2 in the examined patients were evaluated. A comparative analysis of the results shows that one of the main signs of intoxication of the body is an increase in body temperature, which gradually decreases in the comparison group before reaching normal values, Whereas in patients of the main group, normalization of body temperature occurred already by the 5th day of observation. Further, this parameter remained at the level of normal values in the postoperative period.

At the same time, we also found significant differences between the compared groups in terms of LII (P<0.001). There was not only a rapid decrease in this parameter in patients of the main group, but also a significantly rapid normalization of this parameter. Results identical to the LII indicator were obtained for ESR. If the indicators before the start of treatment in the comparison groups were high, then in patients of the main group on the 5th day they decreased significantly to the level of normal values (P<0.001). Whereas, these indicators in the comparison group did not decrease to normal values in the above-mentioned periods and remained at a high level.

A comparative analysis of SaO2 saturation indicators revealed the following points. During the examination, it was revealed that this indicator remains at a low level in patients of the comparison group despite the implementation of basic therapeutic measures aimed at detoxification of the patient's body. When performing the improved method of detoxification of the body with the use of discrete plasmapheresis, saturation indicators were already within normal values by the 3rd day of treatment (P<0.001).

Thus, the study of indicators of intoxication of the body (T – body, L – blood, MVM (standard units), LII, ESR, SaO2) in patients with purulent-necrotic complications of DFS with systemic inflammatory response syndrome (SIRS) showed that in all patients of both groups, upon admission, the above parameters were significantly increased relative to normal values (P<0.001). But after the plasmapheresis performed according to the method we proposed, these indicators decreased. At the same time, it should be emphasized that these parameters tended to change unidirectionally, but with different intensity after different methods of complex treatment. After the traditional treatment (comparison group), the above parameters decreased gradually, but mostly did not reach normal values. After complex treatment including discrete plasmapheresis, the parameters decreased significantly quickly and reached normal values in a short time. This proves the pronounced detoxification effectiveness of the proposed complex treatment of patients with purulent-necrotic complications of DFS with SIRS.

The analysis of the degree of lesions of the lower extremities showed that the pathological processes on the affected lower extremities in the compared groups of patients were comparable. At the same time, if in patients of the comparison group purulent-necrotic phlegmon was 28.2%, then in the main group it was observed in 28.10%

of cases, respectively. Finger gangrene in patients of the comparison group amounted to 40.25% of the total number of patients, then in the main group these indicators amounted to 40.52% of cases, gangrene of the distal foot was observed in 21.38% and 21.57 cases, respectively. Creeping putrefactive phlegmons of the foot, supraorbital space and shin accounted for 10.06% and 9.80% of cases, respectively. The analysis of concomitant diseases in the comparison groups was also similar, i.e. representative.

It should be emphasized that in the comparison group of 159 patients, the number of amputations performed at various levels of the lower extremities was 197 (123.9%), that is, after performing primary amputation against the background of the progression of the pathological process and wound infection, we resorted to performing reamputation, which served to increase the number of surgical interventions. At the same time, in 153 patients of the main group, the number of amputations performed was 169 (110.5%), respectively.

An analysis of the comparative dynamics of LPI in patients of the comparison group against the background of various methods of correction of the microcirculatory bed showed that in patients of the main group there was a significant clinical and hemodynamic improvement with a significant increase in LPI (fig. 7, 8).

It is known that the normal indicators of oxygen saturation of wound tissues are 45.5±0.5 mmHg. As can be seen from fig. 9, the initial level of TcPO2 in patients of the comparison group and the main group at admission to the hospital did not differ significantly from each other – 21.2±3.5 mmHg and 21.5±4 mmHg, respectively ($P<0.05$).

But in the future, all the parameters changed with different intensity according to the duration of observation. If in the comparison group the increase in the parameter after treatment was smooth (respectively 21.2±3.5 mmHg; 23.3±3.3 mmHg; 27.2±4.1 mmHg. according to the days of observation), which did not reach normal values in the pre-operational period, then in the main group these parameters increased with greater intensity (respectively 21.5±4 mm) after conducting sessions with

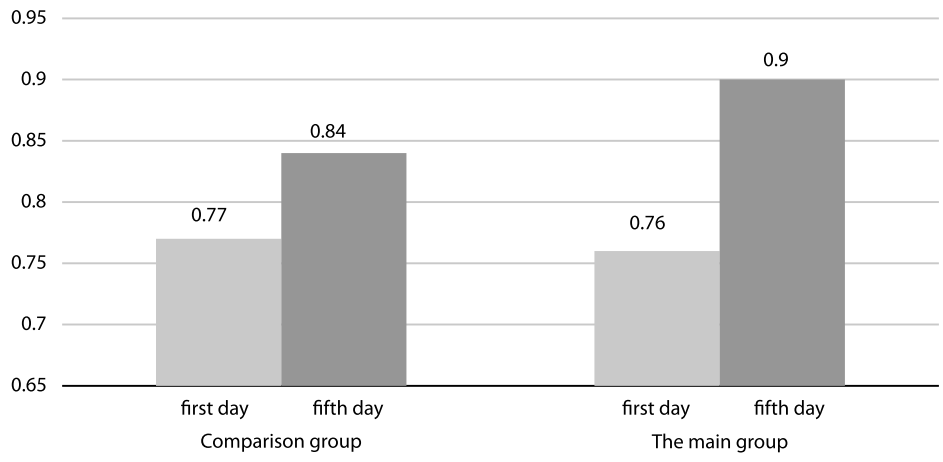

Fig. 7. The dynamics of LPI in patients who received sessions with electromagnetic radiation with a Barva-Flex photonic matrix emitter in comparison with the control group

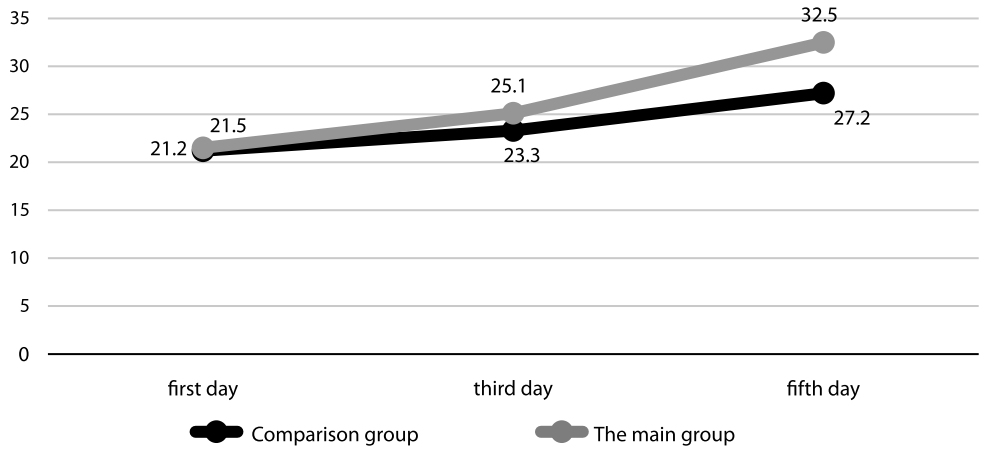

Fig. 8. Comparative dynamics of tissue oxygen saturation ($TcPO_2$) in patients with purulent-necrotic lesions of the lower extremities in DFS with SIRS mmHg

electromagnetic radiation with a Barvaflex photonic matrix emitter using the methods proposed by us (patent for the invention of the Republic of Uzbekistan No. IAP 07441 on 05/19/2023) mercury; 25.1±3.6 mmHg; 32.5±4.0 mmHg. according to the days of observation), in most cases reaching thresholds indirectly confirming the viability of soft at the assumed level of lower limb truncations already on the 3rd day of treatment.

Thus, the dynamics of studying the oxygen saturation of wound tissues ($TcPO_2$) at the intended level of amputations in patients with purulent-necrotic lesions in diabetic foot syndrome showed that after the treatment measures in both compared groups, $TcPO_2$ tended to increase the initially reduced parameter, but with different intensity if the parameters in the comparison group and after 5 the days did not reach the level that allowed predicting the healing of the amputation stump, in the main group, this parameter reached these values after conducting 3 sessions of electromagnetic radiation with the Barvaflex photonic matrix emitter. Improving the dynamics of oxygen saturation of tissues at the expected amputation level allowed the limb to be truncated at the intended level by the operating surgeon, rather than proximally (above).

The state of the hemostasis system in the compared groups against the background of the complex of measures carried out, we did not identify any significant differences in the comparative analysis, that is, they were comparable.

Prior to the start of correction of impaired microcirculation in the lower extremities, all patients showed a significant decrease in the rate of main blood flow, average blood flow rate and pulse index in the peripheral arteries. These indicators did not have a tendency to significantly improve in patients of comparison group a, in patients of the main group, the above indicators after conducting sessions with electromagnetic radiation with a Barvaflex photonic matrix emitter tended to significantly improve (table 2).

Analysis of the results of surgical treatment (amputation of limbs) in the control group of patients showed that against the background of a complex of therapeutic measures, 38 (23.9%) patients of the studied group showed progression of both the pathological process at the level of amputation (purulent necrotic complication) and signs of SIRS.

Table 2
Dopplerography and Dopplerometry data in patients of the studied groups

Indicator	Comparison group		The main group		Standard
	first day	fifth day	first day	fifth day	
Average blood flow rate (cm/s)	0.77±0.02	1.21±0.17	0.76±0.03	1.24±0.12	1.62±0.13
Linear blood flow rate (cm/s)	4.88±1.54	5.07±0.36	4.90±1.50	5.14±0.40	6.12±0.97
Pulse index	5.01±0.46	5.52±0.36	5.10±0.41	6.61±0.42	9.8±1.1

Analysis of the results of surgical treatment (amputation of limbs) in the main group of patients showed that, against the background of a set of measures, 16 (10.5%) patients of the studied group showed progression of both the pathological process at the level of amputation (purulent necrotic complication) and signs of SIRS.

A comparative analysis of purulent-necrotic complications caused by lower limb reamputations at a higher level showed that if purulent-necrotic complications from the amputation stump of the fingers in the comparison group amounted to 8.8%, then in the main group these complications were observed in 3.9% of patients. The progression of wound infection at the foot level in the comparison group was 6.3%, then in the main group of patients 3.3% of cases. The progression of wound infection from the amputation stump of the lower leg in the comparison group was observed in 3.9% of patients, then these indicators in the main group amounted to 3.3% of cases. The progression of wound infection from the amputation stump of the hip in the comparison group was 1.9%, in the main group such complications were not observed (fig. 9).

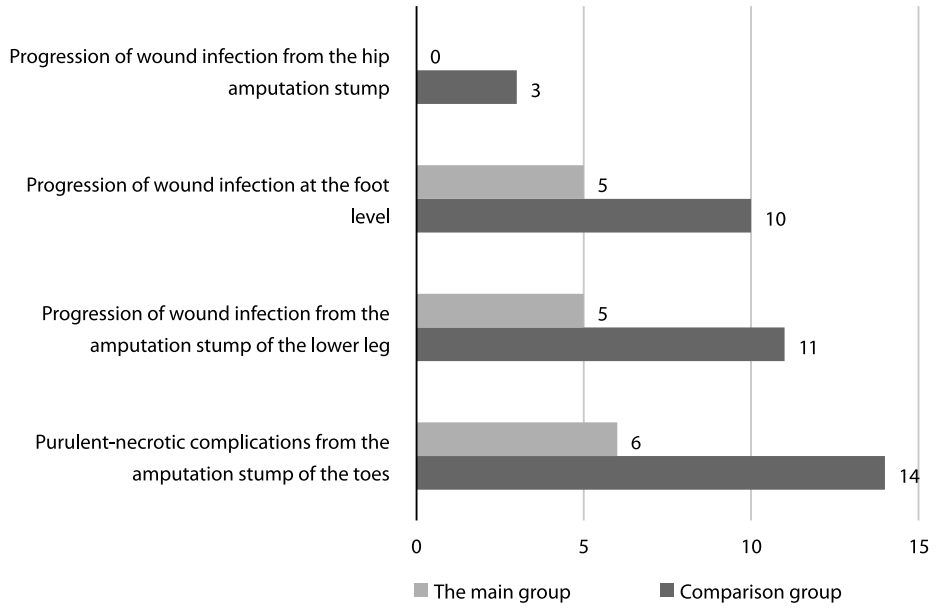

Fig. 9. Purulent-necrotic postoperative complications in the compared groups

Table 3
Causes of deaths in patients in the study groups

Reasons	Comparison group		The main group	
	Abs.	%	Abs.	%
Acute heart failure	3	1.9	1	0.65
Uncontrollable hypotension	2	1.3	1	0.65
Pulmonary embolism	2	1.3	1	0.65
Kidney failure	3	1.9	–	
Multiple organ dysfunction	9	5.7	3	1.96
Total	19	11.95	6	3.92

A comparative analysis of the causes of deaths in the comparison groups showed that if the fatal outcome in patients of the control group was 11.95% of cases, then in patients of the main group this indicator significantly decreased to 3.92% of cases (table 3).

Based on the conducted research, we have developed an algorithm for determining the optimal (proper) level of amputations of the lower extremities in patients with purulent-necrotic complications of DFS with SIRS, which is based on determining the viability

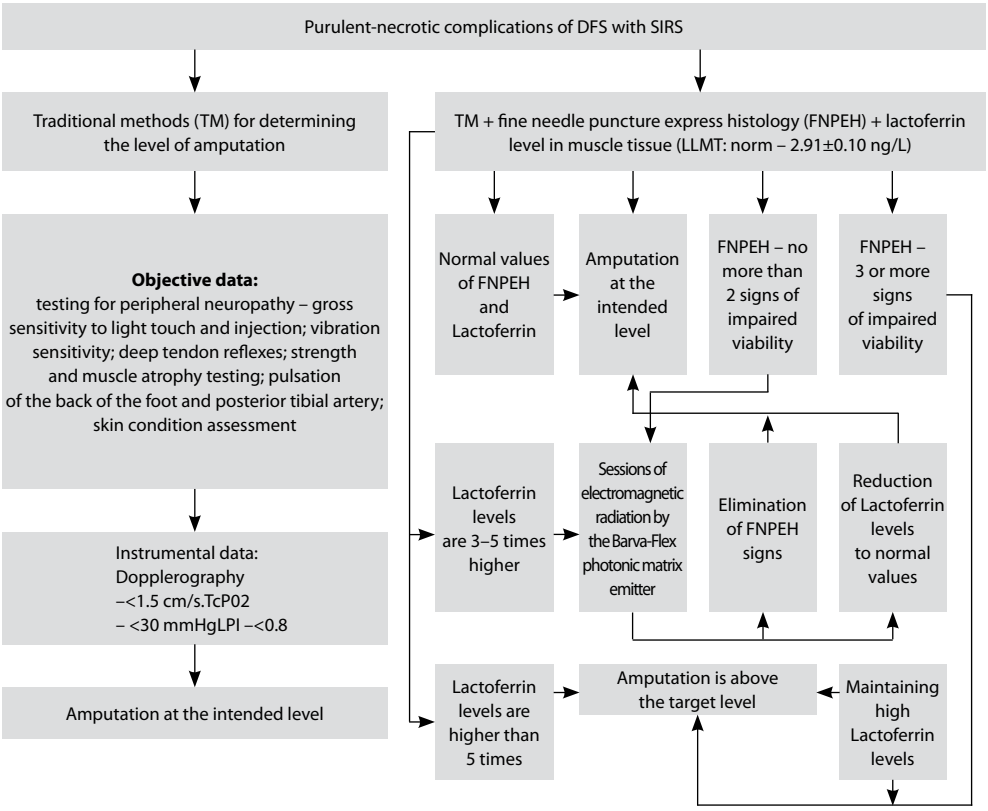

Fig. 10. Algorithm for determining the optimal (proper) level of lower limb amputations in patients with purulent-necrotic complications of DFS with SIRS

of muscle tissue by express histology taken by fine needle puncture using a special needle at the assumed level of limb truncation, as well as determining the level of Lactoferrin in tissue fluid (fig. 10).

The developed algorithm makes it possible to radically change the stratification of amputations at one level or another based on the implementation of the principles of routine methods for determining the expected level of limb truncation, towards optimization, which minimizes the number of unjustified higher crippling limb amputations, leading to profound disability and a significant decrease in the quality of life of patients.

■ CONCLUSIONS

Factor analysis of unsatisfactory results after performed amputations at various levels of the lower extremities showed that the methods used to determine the viability of soft tissues at the assumed level of truncation of the lower limb in terms of predicting necrosis and the development of purulent necrotic process in the area of amputation stump are not informative. A high percentage of purulent-necrotic complications from amputation stump and re-amputations (23.9%) indicate the need to develop optimal methods for determining viability at the level of the proposed amputation of the lower limb.

Conducting sessions of electromagnetic radiation with a Barva-Flex photonic matrix emitter with questionable (no more than two) signs of viability of muscle tissue leads to a significant improvement in the dynamics of oxygen saturation of tissues and their survival at the assumed amputation level, which allows for limb truncation at the level intended by the surgeon and not distally. The use of a method to combat SIRS in the form of discrete plasmapheresis significantly affects the outcome of the disease, which is expressed in a significant reduction in the number of adverse outcomes of the disease.

The application of the developed algorithm makes it possible to radically change the stratification of amputations at one level or another, based on the implementation of the principles of routine methods for determining the estimated level of limb truncation towards optimization, which minimizes the number of unjustified high limb amputations from 23.9% to 10.5% and deaths from 11.95% to 3.92% of cases, respectively.

■ REFERENCES

1. Grigoropoulou, Pinelopi, et al. Diabetic foot infections: an update in diagnosis and management. *Current diabetes reports*. 2017;17:1–12. DOI: 10.1007/s11892-017-0831-1
2. Mairghani, Maisoon. Diabetic Foot Ulcers (DFU) in Bahrain; An Epidemiological Profile of the Prevalence, Clinical Care, Economic Cost and Impact on Quality of Life. Diss. Royal College of Surgeons in Ireland, 2022. https://doi.org/10.25419/rcsi.20509446.v1
3. Navarro-Flores, Emmanuel, and Omar Cauli. Quality of life in individuals with diabetic foot syndrome. *Endocr Metab Immune Disord Drug Targets.* 2020;20(9):1365–1372. DOI: 10.2174/1871530320666200128154036
4. Rodríguez-Sánchez, Beatriz and Alan Sinclair. Health economics of diabetic foot disease: costs of diabetic neuropathy and diabetic foot. *Diabetic Neuropathy. Elsevier.* 2022;211–221. DOI: 10.1016/B978-0-12-820669-0.00017-7
5. Bairamkulov A.A., Vorotnikov A.A. Biochemical and clinico-morphological criteria for the diagnosis of diabetic foot. *Science. Innovation. Technology*. 2016;3:243–250. (in Russian)
6. Mavrogenis, Andreas F., et al. Current concepts for the evaluation and management of diabetic foot ulcers. *EFORT open reviews.* 2018;3(9):513–525. DOI: 10.1302/2058-5241.3.180010
7. Costa, Davide, et al. Social aspects of diabetic foot: a scoping review. *Social Sciences.* 2022;11(4):149. DOI: 10.3390/socsci11040149
8. Guest, Julian F., Graham W. Fuller and Peter Vowden. Diabetic foot ulcer management in clinical practice in the UK: costs and outcomes. *International wound journal.* 2018;15(1):43–52. DOI: 10.1111/iwj.12816
9. Siersma, Volkert, et al. Diabetic complications do not hamper improvement of health-related quality of life over the course of treatment of diabetic foot ulcers – the Eurodiale study. *Journal of Diabetes and its Complications.* 2017;31(7):1145–1151. DOI: 10.1016/j.jdiacomp.2017.04.008

10. Silina E.V., Stupin V.A., Gabitov R.N. Collagen role in the mechanisms of chronic wounds healing diabetic foot syndrome. *Klin. med.* 2018;96(2):106–115. DOI: 10.18821/0023-2149-2018-96-2-106-115. (in Russian)
11. Jalilian, Milad, Pegah Ahmadi Sarbarzeh, and Sajad Oubari. Factors related to severity of diabetic foot ulcer: a systematic review. *Diabetes, Metabolic Syndrome and Obesity.* 2020;1835–1842. DOI: 10.2147/DMSO.S256243
12. Uckay, Ilker, et al. An overview on diabetic foot infections, including issues related to associated pain, hyperglycemia and limb ischemia. *Current pharmaceutical design.* 2018;24(12):1243–1254. DOI: 10.1177/2473011418788864
13. Alshammary, Shadi, et al. Economic impact of diabetic foot ulcers on healthcare in Saudi Arabia: a retrospective study. *Annals of Saudi medicine.* 2020;40(5):425–435. DOI: 10.5144/0256-4947.2020.425
14. Khamdamov B.Z., Teshayev S., Khamdamov I.B. Improved method of amputation at shin level in severe forms of diabetic foot syndrome. *Russian Journal of Operative Surgery and Clinical Anatomy.* 2020;4(2):37–40. DOI: 10.17116/operhirurg2020402137
15. Baig, Mirza Shahed, et al. An overview of diabetic foot ulcers and associated problems with special emphasis on treatments with antimicrobials. *Life.* 2022;12(7). DOI: 10.3390/life12071054.
16. Lim, Jonathan Zhang Ming, Natasha Su Lynn Ng, and Cecil Thomas. Prevention and treatment of diabetic foot ulcers. *Journal of the Royal Society of Medicine.* 2017;110(3):104–109. DOI: 10.1177/0141076816688346