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DIABETIC GANGRENE OF THE LOWER EXTREMITIES – ANALYSIS OF TREATMENT RESULTS AND LONG-TERM SURVIVAL OUTCOMES

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Abstract
Diabetic ulcers are not only a common problem but also one of the serious and costly complications of diabetes. Significant risk factors for amputation in patients include: male gender, history of nicotine use, duration of foot ulcers, presence of destructive changes in the foot, and excess body weight. A history of ulcers increases the risk of developing another ulcer in patients with diabetes. Between 20% and 58% of patients develop a new ulcer within a year after wound healing. Studies have shown that patients with recurrent diabetic foot ulcers have a 2.23 times higher rate of amputation compared to patients with primary foot ulcers [7,8,12]. Objective. To study long-term survival and treatment outcomes in patients with diabetic gangrene and necrotic complications (DGNC) after limb amputation at various levels.
Materials and Methods. The study is based on the analysis of treatment results of 559 diabetic patients with complicated purulent-necrotic lesions of the foot (DGNC) from 2020 to 2023.
Results. In the control group, after 1 year of follow-up, 89 patients remained under observation. Of these, 60% retained weight-bearing function of the lower limb following various operations at the foot and toe levels. Thus, the long-term treatment results during the first year were assessed based on the condition of 60 limbs. During the 1-year follow-up, 34 patients (66.7% of the total) were

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hospitalized due to various problems related to the preserved limb pathology. Twenty-six patients (43.3%) did not require inpatient treatment for any issues related to the preserved limb during that year. Among the 34 patients in the control group, hip-level amputation was performed on 2 patients.
During the four-year follow-up of patients in the main group, annual deaths were recorded, with the highest mortality observed during the first and second years. Of the 28 deaths in the second year, 19 patients (67.8%) died with a preserved lower limb, and only 9 with an amputated limb.
Conclusions. According to patient survival criteria, the most favorable outcomes were observed in patients who underwent conservative surgical methods on foot tissues, considering the topographic-anatomical structure and spread of purulent-necrotic lesions in diabetes.

Keywords: Neuroischemic form of diabetic foot syndrome, diabetic ulcer, diabetes mellitus, critical ischemia of the lower extremities.

Introduction

Diabetes mellitus remains one of the most widespread endocrine diseases, significantly impairing patients' quality of life and ultimately reducing life expectancy. Over 415 million people worldwide suffer from diabetes, and alarmingly, its prevalence continues to rise — projections indicate this number will increase to 640 million by 2040 [1]. Currently, a major issue for diabetic patients is the presence of diabetic foot ulcers and their subsequent infections, which frequently lead to limb amputations [2]. Diabetic ulcers are not only a common issue but also one of the most serious and costly complications of diabetes. Significant risk factors for amputation include male gender, a history of nicotine use, long-standing foot ulcers, destructive changes in the foot, and excess body weight [3].
Globally, 40% to 60% of non-traumatic lower limb amputations are associated with complications of diabetes. Studies show that amputations (both major and minor) performed in the context of diabetes have a high mortality rate, with 5-

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year survival ranging from 41% to 48%. Even patients who undergo minor amputations have a 5-year survival rate of only 59% [4–6].

A history of foot ulcers increases the risk of recurrence in diabetic patients. Between 20% and 58% of patients develop a new ulcer within one year of wound healing. Research has shown that patients with recurrent foot ulcers ultimately face a 2.23 times higher rate of amputation compared to those with primary foot ulcers [7,8,12].

Risk factors affecting survival have been studied in patients with diabetic foot ulcers [9,10], as well as in those who have undergone diabetic-related amputations [11,13].

The objective of this study was to analyze long-term survival and treatment outcomes in patients with diabetic gangrene of the lower extremities (DGLE) following limb amputation at various levels.

Materials and Methods

This study is based on an analysis of treatment outcomes in 559 patients with diabetes mellitus who had complicated purulent-necrotic lesions of the foot (diabetic gangrene of the lower extremities, DGLE) during the period from 2020 to 2023.

Patients were divided into two groups based on the treatment methods applied:

- Group I (control group) consisted of 111 patients who were treated at the clinic using a comprehensive, traditional treatment approach.
- Group II (main group) included 448 patients who underwent a conservative foot amputation with removal of the tendon-synovial complex.

In the control group, patients received traditional therapy. Due to unsuccessful attempts to preserve the limb, 39 patients underwent high thigh amputations. Toe disarticulations were performed in 15 cases; following initial treatment, this accounted for 13.5%. In the remaining 50% of patients, various necrectomies were performed to remove purulent-necrotic foci.

In the main group of 448 patients, 14 patients died during hospitalization after treatment. Among them, 5 had functioning lower limbs, and 9 had undergone

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thigh-level amputations. Upon discharge, 434 patients remained, including 54 with thigh amputations and 382 with functioning lower limbs.

In the control group, 5 patients died during inpatient treatment due to various causes. At the time of discharge, 106 patients remained. The causes of death in this group included myocardial infarction (3 cases), acute renal failure, and hypoglycemic coma. These early treatment outcomes in the control group were previously reported in the dissertations of Zhanabayev B.B. and Kamalov T.T. (1996), conducted in the same clinic.

During the 1-year follow-up, an additional 17 discharged patients died due to various causes.

Results

After one year of follow-up, 89 patients remained under observation in the control group. Among them, 60% retained the weight-bearing function of the lower limb due to various surgical procedures performed at the level of the foot and toes. Thus, the long-term treatment outcomes during the first year were assessed based on the functionality of 60 preserved limbs.

Of these 60 patients:

- 34 patients (66.7%) were hospitalized during the year for various complications related to the preserved limb.
- 26 patients (43.3%) did not require inpatient care for any issues with the preserved limb during this period.
- Among the 34 hospitalized patients, 2 underwent thigh-level amputations.

These results reflect the high rate of complications and rehospitalizations even among patients who initially retained limb function, highlighting the severity and ongoing risk associated with diabetic gangrene of the lower extremities.

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General Characteristics of the First Group of Patients in the Long-Term Follow-Up after DGLE

Table1

№	Indicators	Year 0	Year 1	Year 2	Year 3	Year 4	Total
1	**Number of patients**	111 (100%)	106 (100%)	89 (100%)	68 (100%)	45 (100%)	111 (100%)
2	**Number of deaths**	5 (4.5%)	17 (16.0%)	21 (23.6%)	23 (33.8%)	13 (28.9%)	79 (100%)
A	With functioning lower limb	2 (9%)	10 (12.7%)	12 (17.7%)	13 (14.0%)	7 (15.6%)	44 (55.7%)
B	After amputation	3 (2.7%)	7 (9.5%)	9 (13.6%)	10 (14.7%)	6 (13.6%)	35 (44.3%)
3	**Remaining patients**	106 (95.5%)	89 (83.9%)	68 (76.4%)	45 (66.2%)	32 (71.1%)	32 (28.8%)
4	**Including those with functioning lower limb**	70 (100%)	60 (100%)	48 (100%)	35 (100%)	28 (100%)	171 (100%)
A	Of those, hospitalized during the year	—	34 (56.7%)	23 (47.9%)	15 (42.9%)	14 (50.0%)	86 (50.3%)
B	Had no problems with lower limb	—	26 (43.3%)	25 (52.0%)	20 (57.1%)	14 (50.0%)	85 (49.3%)

Similarly, the number of patients was analyzed for each subsequent year of follow-up.

The analysis included the number of deceased patients, and based on these data, the number of functioning limbs—those that were initially affected upon admission to the clinic—was recorded. For each observation period, these cases were taken as 100% for comparison.

During the first year of follow-up, the number of patients who were hospitalized due to complications in the preserved limb was determined. Separately, cases were identified where patients did not seek medical attention for any problems with the preserved limb.

The overall trend analysis shows a progressive decrease in the number of patients in the control group. From the original 111 patients, only 32 patients remained by the end of the fourth year, which corresponds to 28.8% of the initial cohort (see Table 2).

This indicates a high cumulative mortality and/or limb loss rate among patients with diabetic gangrene of the lower extremities (DGLE), even among those who

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initially retained limb function. These findings emphasize the long-term severity of the disease and the need for improved strategies in limb preservation and patient survival.

Table 2. Relationship Between Survival in the Control Group and the Volume of Surgical Intervention for Diabetic Gangrene of the Lower Extremities (DGLE) in Long-Term Follow-Up

№	Type of Surgery	Year 0	Year 1	Year 2	Year 3	Year 4
1	Thigh amputation	39 (35.1%)	36 (33.9%)	29 (32.6%)	20 (29.4%)	10 (22.2%)
2	Disarticulation	15 (13.5%)	14 (13.2%)	9 (10.1%)	9 (13.2%)	6 (13.3%)
3	Necrosectomy	57 (51.4%)	56 (52.9%)	51 (57.3%)	39 (57.4%)	29 (64.5%)
4	Total patients	111 (100%)	106 (100%)	89 (100%)	68 (100%)	45 (100%)

Significant Losses Observed During the First Two Years of Follow-up After Initial Treatment for DGLE:In the first year of follow-up, 17 patients (16%) died, and in the second year, 21 patients (23.6%) passed away. These high mortality rates are attributed to the progression of the underlying disease due to inadequate glycemic control and poor diabetes management—primarily among less educated patients in the control group.Out of 70 initially preserved limbs in the control group, only 28 remained functional by the end of the four-year follow-up period.During this period, 5 additional amputations were performed, which—when combined with the initial amputations—brings the total rate of amputation to 39.6%. Meanwhile, 16 patients experienced no recurrence of diabetic gangrene in the preserved limb from the time of hospital discharge.Additionally, during the follow-up period:

- 11 Sharp amputations (forefoot amputations) were performed,
- 15 toe disarticulations were recorded, with the highest frequency occurring in the first year of observation.

The first two years were thus critical for both limb preservation and overall survival in this patient group. Among the deceased during this early period,

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contributing factors included not only the progression of diabetes but also psychosocial, familial, and financial challenges associated with treatment and recovery.Patients who survived beyond four years were typically those with a high quality of life index, better diabetes education, and effective self-management skills.An analysis of survival over four years after limb amputation, toe disarticulation, or necrotic tissue removal in patients with diabetic gangrene of the lower extremities (DGLE) revealed that 7 out of 39 patients who had undergone amputation were still alive after four years (18% of those amputated). By the fifth year, only 32 patients remained under observation from the original 111.The lowest mortality was observed among those who had undergone toe necrosectomy with preservation of foot anatomy—their number decreased from 57 to 29 cases over four years (see Table 9).At the four-year mark, patients with preserved foot structure dominated, representing 29 out of 45 (or 64.4%) of the remaining patients. This trend is likely due to these patients returning to active lifestyles and employment.

Analysis of Treatment Effectiveness for DGLE Patients in the Control Group Using the Developed Scoring Scale. The analysis (Table No. 3) showed that as the follow-up period increased (up to 4 years), there was a gradual increase in the proportion of unsatisfactory outcomes, primarily due to patient deaths caused by decompensated diabetes and the progression of its complications. Against this background, the proportion of excellent outcomes decreased from 63.1% to 23.4%, and satisfactory outcomes dropped from 32.4% to 5.4%.A separate analysis of treatment outcomes for DGLE during each of the four years of follow-up demonstrated that the share of satisfactory results progressively declined over time (32.4% → 29.2% → 23.6% → 14.7% → 13.3%), while the proportion of excellent results remained relatively stable (63.1% → 50.0% → 49.4% → 50.0% → 57.8%).This pattern is attributed to the poor survival prognosis among patients who underwent lower limb amputation.

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Long-Term Treatment Outcomes in the Control Group of Patients with Diabetic Gangrene of the Lower Extremities (DGLE)

Table No. 3

Outcome	0 years	1 year	2 years	3 years	4 years	Total
Excellent	70 (63.1%)	53 (50.0%)	44 (49.4%)	34 (50.0%)	24 (57.8%)	24 (23.4%)
Good	-	5 (4.7%)	3 (3.4%)	1 (1.5%)	2 (4.4%)	2 (1.8%)
Satisfactory	36 (32.4%)	31 (29.2%)	21 (23.6%)	10 (14.7%)	6 (13.3%)	6 (5.4%)
Unsatisfactory	5 (4.5%)	17 (16.1%)	21 (23.6%)	23 (33.8%)	13 (28.9%)	79 (71.2%)
Total Patients	111 (100%)	106 (100%)	89 (100%)	68 (100%)	45 (100%)	111 (100%)

The main group included 448 patients with diabetic gangrene and necrosis of the foot (DGNF). At the time of discharge from the hospital after treatment, 14 patients had died: 5 with functioning lower limbs and 9 following amputation at the thigh level. Thus, 434 patients remained at discharge, of whom 54 had undergone thigh amputation and 382 had functioning lower limbs. During the four-year follow-up period, patient mortality was recorded annually. The highest number of deaths occurred during the first two years of observation. Specifically, in the second year, of 28 deaths, 19 patients (67.8%) had preserved lower limbs, and 9 had amputated limbs.In the first year after undergoing DGNF treatment, the number of deaths among patients with thigh amputations was higher than among those with preserved limbs (Table No. 4). However, starting from the second year, this trend reversed: in the third year, out of 18 deceased patients, 14 (77.8%) had functioning limbs, and in the fourth year, out of 13 deaths, 10 (76.9%) were patients with preserved limbs. Correspondingly, only 4 and 3 deaths, respectively, occurred in patients with thigh-level amputations. Overall, of the 448 patients admitted to the clinic, 360 remained under observation by the fourth year, and 347 by the fifth year.The rate of hospitalizations due to various complications related to the preserved limb among patients followed for four years ranged from 20.5% to 24.4%.

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General characteristics of the second group of patients in long-term follow-up after diabetic gangrene and necrosis of the foot (DGNF).

Table No. 4.

№		0	1	2	3	4	Total
1	Number of patients	448 (100%)	434 (100%)	406 (100%)	378 (100%)	360 (100%)	448 (100%)
2	Number deceased (total)	14 (3.1%)	28 (6.5%)	28 (6.9%)	18 (4.8%)	13 (3.6%)	101 (100%)
	A. With functioning lower limb	5 (1.1%)	15 (3.5%)	19 (4.7%)	14 (2.7%)	10 (2.8%)	63 (62.4%)
	B. After amputation	9 (2.0%)	13 (3.0%)	9 (2.24%)	4 (1.8%)	3 (0.8%)	38 (37.6%)
3	Patients remaining (total)	434 (96.9%)	406 (93.5%)	378 (93.1%)	360 (95.2%)	347 (96.4%)	347 (77.5%)
	A. Including with functioning lower limb	382 (100%)	371 (100%)	348 (100%)	329 (100%)	318 (100%)	318 (100%)
	B. Hospitalized during the year	-	90 (24.3%)	78 (22.4%)	75 (22.8%)	67 (21.1%)	310 (22.4%)
	C. No problems with lower limb	-	281 (75.7%)	270 (77.6%)	254 (77.2%)	251 (78.9%)	107 (77.6%)

This parameter was highest in the first year of observation (24.3%) and lowest in the fourth year (21.1%).Thus, in the second group of patients who underwent treatment for DGNK, a fairly distinct trend should be noted. It consists in the fact that during the first year of observation, the main losses among deceased patients were those with a preserved limb (13 out of 28 – 46.4%), but starting from the second year of observation, patients with preserved limbs continued to die: 67.8% in the 2nd year and 76.9%–77.8% in the 4th and 3rd years, respectively. The cause of this was the progression of diabetes mellitus due to decreased glycemic control and inadequate correction.

As a result of this trend, the survival structure of patients in the main group in the long-term follow-up after DGNK surgery, depending on the extent of the operation, underwent fewer changes than in the control group. The proportion of surviving patients with amputated limbs slightly decreased only in the first two

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years (from 13.6% to 11.0% – Table 5). In the following years of observation, this indicator remained almost unchanged.

Dependence of survival among patients of the second group on the extent of surgical interventions for DGNK in long-term follow-up.

Table №5.

№	Type of Operation	0	1	2	3	4
1	Hip amputation	61 (13.6%)	48 (11.0%)	39 (9.6%)	35 (9.3%)	32 (8.9%)
2	Sharp amputation	48 (10.7%)	47 (11.0%)	38 (9.4%)	36 (9.5%)	34 (9.4%)
3	Toe exarticulation	88 (19.6%)	88 (20.2%)	82 (20.2%)	74 (20.2%)	64 (18.0%)
4	Necrosectomy	251 (56.0%)	251 (57.8%)	247 (60.8%)	233 (61.6%)	230 (63.7%)
5	Total	448 (100%)	434 (100%)	406 (100%)	378 (100%)	360 (100%)

Characterizing other surgical interventions, it should be noted that there was a slight decrease in the proportion of surviving patients with preserved weight-bearing function of the foot (Sharp's operation): from 10.7% to 9.4%. Approximately the same changes were observed among patients who underwent toe exarticulation (from 19.6% to 18%). Against this background, however, a steady increase in the proportion of surviving patients who underwent the minimal operation was noted: 56% in the early follow-up period, then 57.8%, 60.8%, 61.6%, and 63.7% at 1, 2, 3, and 4 years of follow-up, respectively.

Analysis of the effectiveness of conservative excision methods of the purulent-necrotic focus in patients of the main group with diabetic gangrene of the lower limb showed that at hospital discharge in the early follow-up period, excellent results were recorded in 334 out of 448 cases (74.6%), good results with preserved weight-bearing function in 48 cases (10.7%), satisfactory results in 52 cases (11.6%), and unsatisfactory results in 14 cases (3.1%).

In the long-term follow-up, the highest proportion of unsatisfactory results among patients observed at these time points was recorded in the 1st and 2nd years, accounting for 6.5% and 6.9%, respectively. In the following years, this indicator decreased to 4.8% and 3.6%, however, the cumulative rate of unsatisfactory results four years after diabetic gangrene of the lower limb in the second group amounted to 22.8% (101 deaths out of 448 patients). This occurred against the

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backdrop of almost a twofold decrease in the proportion of satisfactory results (down to 7.1%) (Table No. 6).

Evaluation of Treatment Effectiveness in the Main Patient Group

Table No. 6

Result	**0**	**1**	**2**	**3**	**4**	**Total**
Excellent	334 (74.6%)	316 (72.8%)	301 (74.1%)	288 (76.2%)	280 (77.8%)	280 (62.5%)
Good	48 (10.7%)	48 (11.0%)	40 (9.9%)	37 (9.8%)	35 (9.7%)	35 (7.8%)
Satisfactory	52 (11.6%)	42 (9.7%)	37 (9.1%)	35 (9.3%)	32 (8.9%)	32 (7.1%)
Unsatisfactory	14 (3.1%)	28 (6.5%)	28 (6.9%)	18 (4.8%)	13 (3.6%)	101 (22.8%)
Total	448 (100%)	434 (100%)	406 (100%)	378 (100%)	360 (100%)	448 (100%)

Preservation of the supporting function of the limb and the ability to lead an active lifestyle allowed 35 out of 48 patients to live more than 4 years. It should be noted that when comparing the changes in results, the proportion of good outcomes remained almost unchanged throughout these years (except for the first year), ranging from 9.9% to 9.7%. Conversely, the proportion of satisfactory outcomes gradually decreased year by year, from 11.6% to 8.9%. As a result, after 4 years, only 32 (8.9%) of the 61 patients who lost a lower limb survived.

Conclusions:

According to patient survival criteria, the most favorable outcomes were observed in patients treated with conservative methods targeting the tissues of the foot, taking into account the topographic-anatomical structure and extent of purulent-necrotic lesions in diabetes mellitus. A high percentage of limb preservation was noted among patients in the main group, where conservative excision of altered tendon-synovial sheaths and targeted antibiotic therapy were added to traditional treatment methods.

Late hospitalization of a significant portion of patients, presence of intoxication, and a large number of elderly patients with comorbidities created an unfavorable background for comprehensive treatment of purulent-necrotic foot lesions in patients with diabetes mellitus.

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