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

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Abstract
Introduction. 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 sex, a history of nicotine use, duration of foot ulcers, the presence of destructive changes in the foot, and excessive body weight. A history of ulcers increases the risk of developing another ulcer in diabetic patients. In 20–58% of patients, a new ulcer develops within one year after wound healing. Studies have shown that in patients with recurrent foot ulcers, the rate of amputations is ultimately 2.23 times higher than in patients with primary foot ulcers [7,8,12].
Objective. To study long-term survival and treatment outcomes in patients with diabetic gangrene of the lower limbs (DGL) after limb amputation at various levels.
Materials and Methods. The study is based on the analysis of treatment outcomes in 559 diabetic patients with complicated purulent-necrotic lesions of the foot (DGL) over the period from 2020 to 2023.
Results. During the follow-up of the control group, after 1 year, 89 patients remained under observation. Of these 89 patients, 60% retained weight-bearing function of the lower limb due to various operations performed at the level of the foot and toes. Thus, the long-term treatment outcomes during the first year of follow-up were evaluated based on the functioning of 60 limbs. During one year of observation, 34 of the 60 patients were hospitalized for various reasons related to the pathology of the preserved limb, which accounted for 66.7% of the total patients. Twenty-six (43.3%) patients did not require inpatient treatment for any issues with the preserved limb during that year. In the 34 patients of the control group, amputation at the hip level was performed in 2 patients.
Over the four-year follow-up period of the main group, patient deaths were recorded annually, with the highest mortality occurring during the first and second years of observation. For example, of 28 cases in the second year, 19 patients died with a preserved lower limb (67.8%) and only 9 with an amputated limb.
Conclusions. According to patient survival criteria, the most favorable outcomes were observed in patients who received conservative interventions on the foot tissues, taking into account the topographic-anatomical structure and the extent of purulent-necrotic lesions in diabetes.
Keywords: neuro-ischemic form of diabetic foot syndrome, diabetic ulcer, diabetes mellitus, critical ischemia of the lower limbs.

Introduction

Diabetes mellitus remains the leading among the most common endocrine diseases, seriously reducing patients' quality of life and subsequently leading to a shortened life expectancy.

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Worldwide, more than 415 million people suffer from diabetes, and what is alarming is that the prevalence of diabetes continues to grow, with this number expected to rise to 640 million by 2040 [1].

Currently, the dominant problem for patients is the presence of diabetic ulcers and their infection, which often leads these patients to limb amputation [2]. 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 sex, a history of nicotine use, the duration of existing foot ulcers, the presence of destructive changes in the foot, and excessive body weight [3].

Approximately 40% to 60% of the causes of non-traumatic lower limb amputations worldwide are complications of diabetes. Studies show that amputations (including major and minor amputations) performed in the context of diabetes have high mortality rates, with 5-year survival ranging from 41% to 48%. Even in patients with minor amputations, 5-year survival is only 59% [4–6].

A history of ulcers increases the risk of developing another ulcer in diabetic patients. In 20–58% of patients, a new ulcer develops within one year after wound healing. Studies have shown that in patients with recurrent foot ulcers, the rate of amputations is ultimately 2.23 times higher than in patients with primary foot ulcers [7,8,12].

Risk factors associated with survival have been studied in patients with diabetic foot ulcers [9,10], as well as in patients with diabetic amputations [11,13].

The objective of this study was to investigate long-term survival and treatment outcomes in patients with diabetic gangrene of the lower limbs (DGL) after limb amputation at various levels.

Materials and Methods

The study is based on an analysis of the treatment outcomes of 559 patients with diabetes mellitus complicated by purulent-necrotic lesions of the feet (diabetic gangrene of the lower limbs, DGL) over the period from 2020 to 2023.

Patients were divided into two groups according to the treatment methods used: 111 patients formed Group I (control), who were treated in the clinic and received comprehensive treatment according to the traditional regimen. The second group included 448 patients who underwent conservative foot amputation with removal of the tendon-synovial complex.

In the control group, patients received traditional treatment, and due to unsuccessful attempts to preserve the lower limb, 39 high-level amputations of the thigh were performed. Exarticulations of the toes were performed in 15 cases, after the initial treatment – 13.5%, respectively. In the remaining 50% of patients, various necrectomies were performed to remove purulent-necrotic foci.

The main group included 448 patients, of whom 14 patients died during hospitalization following the performed treatment. Of these, 5 had functioning lower limbs, and 9 had undergone thigh amputation. At discharge, 434 patients remained, including 54 with thigh amputations and 382 with functioning lower limbs.

During the inpatient treatment period in this group, 5 patients died for various reasons, leaving 106 patients at the time of discharge. Causes of death included myocardial infarction (3 cases), acute renal failure, and hypoglycemic coma.

These were the short-term treatment outcomes of the control group, as reported in the dissertations of Zhanabaev B.B. and Kamalov T.T. (1996). These studies were conducted in our clinic. During 1 year of follow-up, 17 of the discharged patients died for various reasons.

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Results

As a result of the follow-up of the control group, after 1 year under observation, 89 patients remained. Of these 89 patients, 60% retained weight-bearing function of the lower limb due to various operations performed at the level of the foot and toes. Thus, the long-term treatment outcomes during the first year of follow-up were evaluated based on the functional status of 60 limbs.

During the 1-year follow-up, 34 of these 60 patients were hospitalized for various reasons related to pathology of the preserved limb, which accounted for 66.7% of the total number of patients. Twenty-six patients (43.3%) did not require inpatient treatment for any problems with the preserved limb during this year. Among the 34 patients in the control group, thigh-level amputation was performed in 2 cases.

General Characteristics of the First Group of Patients During Long-Term Follow-Up After Diabetic Gangrene of the Lower Extremities (DGNE)

Table 1

№	Indicator	0	1	2	3	4	Total
1	Number of patients	111 (100%)	106 (100%)	89 (100%)	68 (100%)	45 (100%)	111 (100%)
2	Of these, deceased	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 these, hospitalized during the year	-	34 (56.7%)	23 (47.9%)	15 (42.9%)	14 (50.0%)	86 (50.3%)
B	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 studied for each subsequent year of follow-up. Among them, the number of deceased patients was recorded, and based on this, data on the number of functioning limbs that were initially affected upon admission to the clinic are presented. These cases were taken as 100% for the given follow-up period.

For the first year of follow-up, the number of patients hospitalized for various reasons related to the preserved limb was determined. Cases in which patients did not seek medical care for pathology of that limb were recorded separately.

Analysis of overall trends shows that, out of the 111 patients in the control group, by the end of the 4th year of follow-up, only 32 patients remained from the original cohort, which accounted for 28.8% (Table 2).

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Dependence of survival among patients in the control group on the extent of surgery for diabetic gangrene of the lower extremities (DGNE) during long-term follow-up
Table 2

№	Type of Surgery	0	1	2	3	4
1	Hip Amputation	39 (35%)	36 (33%)	29 (32.6%)	20 (26.5%)	10 (22.2%)
2	Exarticulation	15 (13.2%)	13 (13.2%)	9 (10.1%)	9 (13.5%)	6 (13.4%)
3	Necroectomy	57 (51.8%)	57 (53.8%)	51 (57.3%)	39 (60.3%)	29 (64.4%)
4	Total	111 (100%)	106 (100%)	89 (100%)	68 (100%)	45 (100%)

Significant losses were observed during the first 2 years of follow-up after patients sought treatment for DGNE. In the first year of observation, 17 patients (16%) died, and in the second year, 21 patients (23.6%) died among those being followed at that time. This was due to progression of the underlying disease as a result of inadequate glycemic control and monitoring in the less adherent part of the control group.
Out of 70 preserved limbs in the control group, only 28 remained functional by the end of the 4-year follow-up after initial admission.
During this 4-year observation period, 5 additional amputations were performed, which, together with the amputations performed at the time of admission, amounted to a total of 39.6%. The number of patients in whom no recurrence of DGNE was observed in the preserved limb since discharge from the clinic was 16.
Additionally, during the follow-up period, 11 cases involved Sharp amputations and 15 cases involved exarticulation of the toes. The highest percentage of these procedures occurred during the first year of observation. The critical period for the functionality of preserved limbs and for patient survival in the control group was the first two years of follow-up. Among patients who died during this period, alongside psycho-emotional, family, and financial difficulties related to hospitalization, the further progression of the underlying disease also played a significant role.
Therefore, patients who reached the four-year survival milestone were those with a high quality-of-life index and a high level of diabetes education, including knowledge of self-monitoring techniques.
The analysis of survival among control group patients with DGNE over a four-year follow-up—after limb amputations, toe exarticulations, or excision of only necrotic tissue of the foot—showed that even four years after surgery, 7 of the 39 patients who had lost limbs were still alive, representing 18% of the total.
By the fifth year of follow-up, 32 of the original 111 patients remained under observation. The lowest losses were observed among patients who underwent necroectomy on the toes with preservation of anatomical structure. Their number decreased from 57 to 29 cases (Table 9).
Over the four-year follow-up, the majority of patients—45 individuals—had full preservation of the foot structure. Of these, 29 patients (64.4% of the observed cohort at that time) maintained full anatomical integrity. This outcome was associated with an active lifestyle and return to work among these patients.

Analysis of the Effectiveness of DGNE Treatment in the Control Group

The analysis of treatment outcomes for patients with DGNE in the control group, using the developed scoring system, revealed (Table 3) that over the follow-up period (up to 4 years) there was a gradual increase in the proportion of unsatisfactory outcomes, mainly due to patient

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deaths from decompensated diabetes and progression of its complications. Against this background, the proportion of excellent outcomes decreased from 63.1% to 23.4%, and satisfactory outcomes decreased from 32.4% to 5.4%.

A year-by-year analysis of treatment outcomes over the 4-year follow-up showed that the proportion of satisfactory outcomes among patients observed during each period progressively declined (32.4% → 29.2% → 23.6% → 14.7% → 13.3%), whereas the proportion of excellent outcomes remained relatively stable (63.1% → 50.0% → 49.4% → 50.0% → 57.8%). This pattern reflects the poor survival prognosis among patients who lost a lower limb.

Long-term Treatment Outcomes of the Control Group of Patients with DGNE

Table 3. Follow-up results

Outcome	0	1	2	3	4	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	111 (100%)	106 (100%)	89 (100%)	68 (100%)	45 (100%)	111 (100%)

In the main group, 448 patients were included. By the time of discharge from the hospital, 14 patients had died. Of these, 5 had preserved lower limbs, and 9 had undergone above-knee amputation. At discharge, 434 patients remained: 54 with above-knee amputation and 382 with preserved lower limbs.

During the four-year follow-up period, patient deaths were recorded annually, with the highest mortality occurring during the first and second years. For example, in the second year, out of 28 deaths, 19 patients had preserved lower limbs (67.8%) and 9 had amputated limbs.

In the first year following DGNE, more deaths occurred among patients after above-knee amputation than among those with preserved limbs (Table 3). However, from the second year onward, this trend reversed. In the third year, of 18 deceased patients with functioning limbs, 14 (77.8%) died. In the fourth year, out of 13 deaths, 10 (76.9%) had preserved limbs. Only 4 and 3 patients, respectively, died after above-knee amputation.

Overall, of the 448 patients admitted to the clinic, 360 remained by the fourth year of follow-up, and 347 remained by the fifth year. Among patients followed for 4 years after DGNE, the rate of hospitalization due to any problems with preserved limbs ranged between 20.5% and 24.4%.

General Characteristics of the Second Group of Patients in Long-term Follow-up After DGNE

Table 3

№	Indicator	0	1	2	3	4	Total
1	Number of patients	448 (100%)	434 (100%)	406 (100%)	378 (100%)	360 (100%)	448 (100%)
2	Deceased (total)	14 (3.1%)	28 (6.5%)	28 (6.9%)	18 (4.8%)	13 (3.6%)	101 (100%)

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A	With preserved 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 (77.45%)
A	Of which with preserved 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%)

The highest proportion of hospitalizations occurred during the first year of follow-up (24.3%), while the lowest was observed in the fourth year (21.1%).

Thus, in the second group of patients who underwent DGNE, one notable trend can be observed. During the first year of follow-up, most deaths occurred among patients with preserved lower limbs (13 out of 28; 46.4%). Starting from the second year, the majority of deaths continued to occur in patients with preserved lower limbs: 67.8% in the second year, and 76.9–77.8% in the third and fourth years, respectively. This trend was primarily due to progression of diabetes mellitus as a result of poor glycemic control and inadequate management.

As a result of this trend, the survival structure of patients in the main group over long-term follow-up after DGNE, depending on the extent of surgery, experienced smaller changes than in the control group. The proportion of surviving patients with an amputated limb decreased slightly only during the first two years (from 13.6% to 11.0%; see Table 4). In subsequent years of observation, this indicator remained almost unchanged.

Dependence of survival in the second group of patients on the extent of surgical interventions for DGNE in long-term follow-up.
Table 4

№	Type of surgery	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	Digit exarticulation	88 (19.6%)	88 (20.2%)	82 (20.2%)	74 (20.2%)	64 (18.0%)
4	Necrectomy	251 (56%)	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, a slight decrease in the proportion of surviving patients with preserved supportive foot function (Sharp operation) was noted: 10.7% → 9.4%.

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Similar changes were observed among patients who underwent digit exarticulation (19.6% → 18%). Against this background, a steady increase in the proportion of surviving patients who underwent minimal surgery was observed: 56% in the immediate follow-up period, increasing to 57.8%, 60.8%, 61.6%, and 63.7% in years 1, 2, 3, and 4, respectively.

Analysis of the effectiveness of conservative removal of purulent-necrotic foci in DGNE patients of the main group showed that at the time of discharge, excellent results were observed in 334 out of 448 cases (74.6%), good results with preserved limb function in 48 cases (10.7%), satisfactory in 52 (11.6%), and unsatisfactory in 14 cases (3.1%).

In long-term follow-up, the highest proportion of unsatisfactory results among patients observed at that time was noted in years 1 and 2, at 6.5% and 6.9%, respectively. In subsequent years, this proportion decreased to 4.8% and 3.6%. However, the total number of unsatisfactory outcomes over four years after DGNE in the second group was 22.8% (101 deaths out of 448 patients). This occurred against the background of an almost twofold decrease in the proportion of satisfactory results (down to 7.1%) (Table 5).

Evaluation of treatment effectiveness in the main group of patients
Table 5

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

Conclusions

Regarding patient survival, the most favorable outcomes were observed in patients who underwent conservative interventions on the foot tissues, taking into account the topographic-anatomical structure and the extent of purulent-necrotic lesions in diabetes. A high proportion of preserved limbs was noted in the main group, where, in addition to traditional treatment methods, conservative excision of altered tendon-synovial sheaths and targeted antibiotic therapy were applied.

Late hospitalization of a significant proportion of patients, the presence of intoxication, and a large number of elderly patients with comorbidities constituted an unfavorable background for the comprehensive treatment of purulent-necrotic foot lesions in diabetic patients.

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