

# Advanced Chronic Kidney Disease as A Limiting Factor for Conventional Limb Salvage in Neuroischemic Diabetic Foot Syndrome

Telman T. Kamalov

Republican Specialized Scientific and Practical Medical Center of Endocrinology, Uzbekistan

Sardorbek S. Begmetov

Republican Specialized Scientific and Practical Medical Center of Endocrinology, Uzbekistan

Article Received: 14/04/2026, Article Accepted: 04/05/2026, Article Published: 31/05/2026

## Abstract

Neuroischemic diabetic foot syndrome in patients with chronic kidney disease is associated with severe peripheral arterial disease, impaired tissue repair, recurrent infectious complications, and high risk of major amputation. Although revascularization remains a cornerstone of limb salvage strategies, the effectiveness of conventional treatment approaches may be substantially limited in patients with advanced renal dysfunction because of restricted feasibility of contrast-enhanced vascular imaging and endovascular correction. To evaluate the effectiveness and limitations of conventional treatment strategies in patients with neuroischemic diabetic foot syndrome and chronic kidney disease depending on the severity of renal dysfunction. This retrospective study included 55 patients with neuroischemic diabetic foot syndrome and chronic kidney disease. Patients were divided into two groups according to renal function severity: Group I included 34 patients with compensated chronic kidney disease (G1-G3a, eGFR  $\geq 45$  ml/min/1.73 m<sup>2</sup>), whereas Group II consisted of 21 patients with decompensated chronic kidney disease (G3b-G5, eGFR  $< 45$  ml/min/1.73 m<sup>2</sup>). Clinical, metabolic, laboratory, vascular, surgical, and postoperative outcomes were analyzed comparatively. Special attention was paid to feasibility of vascular imaging, endovascular treatment, limb preservation, repeated surgical interventions, and mortality. Patients with advanced chronic kidney disease demonstrated more severe ischemic and infectious lesions, higher prevalence of gangrene, larger wound defects, elevated inflammatory markers, anemia, and hypoalbuminemia. Computed tomography angiography was performed significantly less frequently in Group II (28.6% vs 58.8%), while endovascular revascularization procedures were markedly restricted in patients with severe renal dysfunction. Post-angiographic deterioration of renal function occurred in 23.8% of Group II patients compared with 5.9% in Group I. Patients with decompensated chronic kidney disease demonstrated substantially higher rates of repeated surgical procedures, major amputations, reamputations, recurrent necrotic complications, and six-month mortality. Functional limb preservation was achieved in 82.4% of patients in Group I and only 42.9% in Group II. No patients with advanced chronic kidney disease achieved stable long-term “good” treatment outcome. Advanced chronic kidney disease significantly limits the effectiveness of conventional treatment strategies in patients with neuroischemic diabetic foot syndrome. Restricted feasibility of contrast-enhanced vascular imaging and endovascular correction, combined with severe metabolic and inflammatory disturbances, substantially worsens limb salvage outcomes and increases the risk of major amputation and mortality. Development of individualized treatment approaches with reduced nephrotoxic exposure may improve outcomes in this high-risk patient population.

**Keywords:** Neuroischemic diabetic foot syndrome; chronic kidney disease; peripheral arterial disease; limb salvage; endovascular revascularization; contrast-induced nephropathy; diabetic foot; chronic limb-threatening ischemia; major amputation; vascular surgery.

## Introduction

Neuroischemic diabetic foot syndrome remains one of the

most severe and disabling complications of diabetes mellitus and is associated with a high risk of major amputation, recurrent hospitalization, systemic infectious

complications, and mortality. In patients with chronic kidney disease, the clinical course of neuroischemic diabetic foot becomes substantially more aggressive because of the combination of advanced peripheral arterial disease, impaired tissue repair, chronic inflammation, metabolic imbalance, and reduced resistance to infection. As renal dysfunction progresses, patients frequently develop extensive ischemic lesions, deep ulcerative defects, gangrene, and critical limb ischemia requiring complex multidisciplinary management [1, 2].

Restoration of arterial blood flow remains a key component of limb salvage strategies in patients with neuroischemic diabetic foot syndrome. Contemporary treatment approaches are largely based on vascular imaging and endovascular revascularization procedures, including balloon angioplasty and stenting of lower extremity arteries. These interventions may significantly improve tissue perfusion, reduce the extent of necrosis, facilitate wound healing, and decrease the frequency of major amputations [3]. However, the effectiveness of conventional treatment strategies in patients with advanced chronic kidney disease remains limited in routine clinical practice.

One of the major challenges in this patient population is the restricted feasibility of standard contrast-enhanced vascular imaging. Computed tomography angiography and conventional angiographic procedures require the use of iodinated contrast agents, which may worsen renal dysfunction and increase the risk of contrast-induced nephropathy in patients with reduced glomerular filtration rate [4]. As a result, many patients with advanced chronic kidney disease either undergo limited vascular assessment or are excluded from endovascular revascularization procedures despite severe limb ischemia. In such cases, treatment is frequently reduced to repeated local surgical procedures or major amputations without adequate restoration of arterial blood flow [5].

At the same time, advanced chronic kidney disease is associated not only with vascular limitations, but also with profound metabolic and inflammatory disturbances that negatively affect postoperative recovery. Anemia, hypoalbuminemia, persistent systemic inflammation, poor glycemic control, and impaired reparative capacity contribute to delayed wound healing, recurrent infection, repeated surgical interventions, and progression of tissue necrosis. Consequently, patients with severe renal dysfunction often demonstrate unfavorable long-term outcomes even after technically adequate surgical treatment [6, 7].

Despite the growing number of patients with combined neuroischemic diabetic foot syndrome and chronic kidney disease, the limitations of conventional limb salvage strategies in this category of patients remain insufficiently characterized. Better understanding of the relationship between renal dysfunction, feasibility of vascular correction, and treatment outcomes may help identify the major factors limiting the effectiveness of standard therapeutic approaches and support the development of more individualized treatment strategies.

The aim of the study was to evaluate the effectiveness and

limitations of conventional treatment strategies in patients with neuroischemic diabetic foot syndrome and chronic kidney disease depending on the severity of renal dysfunction.

## Methods

This retrospective observational study included 55 patients with neuroischemic diabetic foot syndrome and chronic kidney disease who underwent surgical treatment using conventional diagnostic and therapeutic approaches. All patients were treated in a specialized multidisciplinary surgical center and were divided into two subgroups according to the severity of renal dysfunction. Group I included 34 patients with compensated chronic kidney disease corresponding to stages G1-G3a with estimated glomerular filtration rate (eGFR)  $\geq 45$  ml/min/1.73 m<sup>2</sup>. Group II consisted of 21 patients with decompensated chronic kidney disease corresponding to stages G3b-G5 with eGFR  $< 45$  ml/min/1.73 m<sup>2</sup>.

The diagnosis of neuroischemic diabetic foot syndrome was established based on clinical examination, assessment of peripheral arterial circulation, ulcerative and necrotic lesions of the foot, and instrumental vascular evaluation. All patients underwent comprehensive clinical, metabolic, laboratory, and vascular assessment. Clinical analysis included evaluation of diabetes duration, comorbid cardiovascular disease, ischemic pain at rest, presence of gangrene, infection of soft tissues, and severity of foot lesions according to the Wagner and WiFi classifications.

Laboratory assessment included fasting blood glucose, glycated hemoglobin (HbA1c), lipid profile, hemoglobin level, leukocyte count, C-reactive protein, serum creatinine, blood urea, serum albumin, and estimated glomerular filtration rate. Renal function staging was performed according to eGFR values calculated during hospitalization.

Instrumental vascular evaluation included ankle-brachial index measurement, duplex ultrasonography of lower extremity arteries, computed tomography angiography when clinically feasible, and assessment of the possibility of endovascular revascularization procedures. Particular attention was paid to the feasibility and limitations of contrast-enhanced vascular imaging in patients with advanced chronic kidney disease because of the risk of contrast-induced renal deterioration.

All patients underwent surgical treatment of different extent depending on the severity of ischemic and infectious-necrotic lesions. Surgical procedures included debridement and necrosectomy, toe amputations, foot resections, below-knee amputations, above-knee amputations, and hip disarticulation. Endovascular revascularization procedures, including balloon angioplasty and stenting, were performed selectively when vascular anatomy and renal function allowed conventional contrast-based angiographic assessment.

Early postoperative outcomes included evaluation of wound dimensions, persistence of tissue necrosis, microbiological contamination, presence of resistant bacterial flora, and systemic inflammatory response

syndrome. Late postoperative assessment included analysis of granulation tissue formation, stump complications, recurrent purulent-necrotic lesions, repeated surgical procedures, reamputations, limb preservation, repeated hospitalization, deterioration of renal function after angiographic procedures, and six-month mortality. Final treatment outcomes were classified as good, satisfactory, or unsatisfactory according to preservation of anatomical and functional integrity of the limb and the absence of major complications during follow-up.

Statistical analysis was performed using descriptive methods. Quantitative data were presented as mean values with standard deviation, whereas categorical variables were expressed as absolute numbers and percentages. Comparative analysis between the two study groups was performed to evaluate the impact of renal dysfunction

severity on vascular treatment feasibility and clinical outcomes in patients with neuroischemic diabetic foot syndrome.

## Results

Baseline clinical and metabolic assessment demonstrated that patients with advanced chronic kidney disease had a substantially more severe clinical profile of neuroischemic diabetic foot syndrome. Patients from Group II were characterized by longer diabetes duration, more frequent arterial hypertension, higher prevalence of ischemic pain at rest, larger and deeper ulcerative lesions, and increased frequency of gangrene and soft tissue infection. Severe ischemic lesions classified as WiFi category 3B were observed almost twice as often in patients with decompensated renal dysfunction (table 1).

**Table 1. Baseline clinical, metabolic, and local characteristics of patients with neuroischemic diabetic foot syndrome and chronic kidney disease**

Parameter	Group I (n=34)	Group II (n=21)
Diabetes duration, years	10.1±4.2	11.8±4.8
HbA1c, %	8.7±1.0	9.2±1.2
Hemoglobin, g/L	117±10	104±12
C-reactive protein, mg/L	9.6±3.4	14.8±5.1
eGFR, ml/min/1.73 m <sup>2</sup>	52±6	28±5
Gangrene, n (%)	6 (17.6%)	8 (38.1%)
Soft tissue infection, n (%)	14 (41.2%)	13 (61.9%)
Ischemic pain at rest, n (%)	11 (32.4%)	15 (71.4%)
Mean wound area, cm <sup>2</sup>	4.8±1.5	6.2±2.1
WiFi category 3B, n (%)	10 (29.4%)	12 (57.1%)

Patients with advanced chronic kidney disease additionally demonstrated more pronounced inflammatory and metabolic disturbances, including anemia, hypoalbuminemia, elevated inflammatory markers, and poorer glycemic control. These abnormalities were associated with larger wound defects, more severe ischemia, and higher frequency of infectious complications.

Vascular assessment revealed extensive peripheral arterial

disease in both study groups; however, the feasibility of conventional contrast-based vascular imaging and endovascular correction was markedly restricted in patients with severe renal dysfunction. Computed tomography angiography and endovascular revascularization procedures were performed significantly less frequently in Group II because of the risk of contrast-induced deterioration of renal function. As a result, many patients with advanced chronic kidney disease underwent only local surgical procedures without полноценной vascular correction (table 2).

**Table 2. Vascular assessment and feasibility of endovascular treatment in patients with neuroischemic diabetic foot syndrome and chronic kidney disease**

PARAMETER	Group I (n=34)	Group II (n=21)
Ankle-brachial index <0.7, n (%)	30 (88.2%)	20 (95.2%)
Tibial artery occlusion, n (%)	24 (70.6%)	17 (81.0%)
Critical popliteal blood flow reduction, n (%)	21 (61.8%)	18 (85.7%)
CT angiography performed, n (%)	20 (58.8%)	6 (28.6%)
Balloon angioplasty performed, n (%)	19 (55.9%)	2 (9.5%)
Stenting procedures performed, n (%)	5 (14.7%)	0
Post-angiographic renal deterioration, n (%)	2 (5.9%)	5 (23.8%)

Analysis of surgical management demonstrated that

patients with decompensated chronic kidney disease required more extensive and repeated procedures. The

frequency of high amputations, repeated operations, and hip disarticulation was substantially greater in Group II. In many cases, progressive ischemia and inability to perform

adequate revascularization resulted in proximal extension of necrotic lesions and failure of limb salvage attempts (table 3).

**Table 3. Surgical treatment characteristics in patients with neuroischemic diabetic foot syndrome and chronic kidney disease**

PARAMETER	Group I (n=34)	Group II (n=21)
Repeated surgical procedures, n (%)	7 (20.6%)	11 (52.4%)
Below-knee amputation, n (%)	6 (17.6%)	8 (38.1%)
Above-knee amputation, n (%)	6 (17.6%)	11 (52.4%)
Hip disarticulation, n (%)	2 (5.9%)	3 (14.3%)
Persistent tissue necrosis, n (%)	7 (20.6%)	13 (61.9%)
SIRS $\geq 2$ criteria, n (%)	6 (17.6%)	12 (57.1%)
Reamputation, n (%)	2 (5.9%)	6 (28.6%)

Late postoperative and overall treatment outcomes demonstrated a marked deterioration of limb salvage effectiveness with progression of renal dysfunction. Preservation of anatomical and functional integrity of the limb was achieved significantly more frequently in Group I, whereas patients with advanced chronic kidney disease

had substantially higher rates of repeated hospitalization, recurrent necrotic complications, major amputation, and mortality. No patients from Group II achieved stable long-term «good» treatment outcome according to the final assessment criteria (table 4).

**Table 4. Final treatment outcomes in patients with neuroischemic diabetic foot syndrome and chronic kidney disease**

PARAMETER	Group I (n=34)	Group II (n=21)
Functional limb preservation, n (%)	28 (82.4%)	9 (42.9%)
Anatomical limb preservation, n (%)	21 (61.8%)	5 (23.8%)
Repeated hospitalization, mean $\pm$ SD	0.9 $\pm$ 0.6	1.6 $\pm$ 0.8
Good treatment outcome, n (%)	10 (29.4%)	0
Satisfactory treatment outcome, n (%)	12 (35.3%)	3 (14.3%)
Unsatisfactory treatment outcome, n (%)	10 (29.4%)	14 (66.7%)
Six-month mortality, n (%)	2 (5.9%)	4 (19.0%)

Overall, patients with advanced chronic kidney disease demonstrated markedly worse vascular, surgical, and functional outcomes despite application of conventional treatment strategies. Restricted feasibility of contrast-enhanced vascular imaging and endovascular correction, combined with severe metabolic and inflammatory disturbances, substantially reduced the effectiveness of limb salvage treatment in this category of patients.

## Discussion

The present study demonstrated that the severity of chronic kidney disease substantially influences both the clinical course and treatment outcomes of neuroischemic diabetic foot syndrome. Patients with advanced renal dysfunction exhibited more severe ischemic lesions, larger and deeper ulcerative defects, higher rates of gangrene and infection, and markedly worse surgical and functional outcomes compared with patients with preserved renal function. These findings confirm that chronic kidney disease is not merely a concomitant condition in patients with diabetic foot syndrome, but rather a major factor limiting the effectiveness of conventional limb salvage strategies [8, 9].

One of the most important observations of the study was the restricted feasibility of conventional vascular imaging and endovascular treatment in patients with advanced chronic kidney disease. Although severe peripheral arterial disease was identified in the majority of patients from both study groups, computed tomography angiography and endovascular revascularization procedures were performed significantly less frequently in Group II because of the risk of contrast-induced renal deterioration. Consequently, many patients with severe renal dysfunction underwent only local surgical procedures without adequate restoration of arterial blood flow. This limitation appears to be one of the key mechanisms contributing to progression of ischemia, recurrent necrosis, repeated operations, and major amputations in this patient population [10].

The study also demonstrated that advanced chronic kidney disease is associated with profound metabolic and inflammatory disturbances that negatively affect wound healing and postoperative recovery. Patients with severe renal dysfunction had more pronounced anemia, hypoalbuminemia, elevated inflammatory markers, and poorer glycemic control. These abnormalities were

accompanied by larger wound defects, persistent tissue necrosis, increased microbiological contamination, and higher frequency of systemic inflammatory response syndrome. Such findings suggest that the unfavorable course of neuroischemic diabetic foot syndrome in advanced chronic kidney disease is determined not only by impaired arterial perfusion, but also by reduced reparative capacity and chronic systemic inflammation [11, 12].

Another clinically important finding was the high frequency of repeated surgical procedures and proximal amputations in patients with decompensated chronic kidney disease. More than half of the patients from Group II required repeated interventions, while major amputations at the level of the thigh were performed substantially more often than in patients with compensated renal dysfunction. In many cases, progressive ischemia and inability to perform adequate vascular correction resulted in proximal extension of necrotic lesions and failure of previous limb salvage attempts. These observations indicate that conventional treatment approaches may become insufficient once advanced chronic kidney disease significantly limits revascularization possibilities [13].

The marked difference in long-term outcomes between the two study groups further emphasizes the clinical significance of renal dysfunction severity. Functional limb preservation and favorable treatment outcomes were achieved predominantly in patients with compensated chronic kidney disease, whereas no patients with advanced renal dysfunction achieved stable long-term «good» outcome according to the final assessment criteria. High rates of repeated hospitalization, reamputation, and mortality in Group II indicate that advanced chronic kidney disease substantially worsens both surgical prognosis and overall survival in patients with neuroischemic diabetic foot syndrome.

The results of the present study support the concept that conventional treatment strategies remain important but have substantial limitations in patients with advanced chronic kidney disease. Standard contrast-based vascular imaging and endovascular procedures may be poorly tolerated or technically restricted in this category of patients, while isolated local surgical management without adequate revascularization often fails to provide stable limb preservation. These findings underline the need for more individualized multidisciplinary approaches aimed at reducing nephrotoxic exposure, improving vascular assessment, and expanding the possibilities of safe revascularization in patients with severe renal dysfunction [14, 15].

Several limitations of the study should be acknowledged. The investigation had a retrospective single-center design and included a relatively limited number of patients. Endovascular treatment strategies were evaluated within the framework of conventional contrast-based approaches without analysis of alternative low-nephrotoxic imaging methods [16, 17]. In addition, long-term functional outcomes beyond the six-month follow-up period were not assessed. Further prospective studies focused on nephroprotective vascular imaging techniques and individualized revascularization strategies may help

improve treatment outcomes in patients with neuroischemic diabetic foot syndrome and advanced chronic kidney disease.

## Conclusion

Advanced chronic kidney disease substantially worsens the clinical course and treatment outcomes of neuroischemic diabetic foot syndrome. Patients with severe renal dysfunction demonstrated more extensive ischemic and infectious lesions, higher frequency of gangrene, persistent tissue necrosis, repeated surgical interventions, major amputations, and mortality compared with patients with compensated renal function. One of the principal factors limiting the effectiveness of conventional treatment strategies in this category of patients was the restricted feasibility of standard contrast-enhanced vascular imaging and endovascular revascularization procedures. In many patients with advanced chronic kidney disease, the risk of contrast-induced renal deterioration limited the use of angiographic assessment and prevented adequate restoration of arterial blood flow, resulting in progression of ischemia and failure of limb salvage attempts. The obtained results indicate that conventional treatment approaches alone may be insufficient in patients with neuroischemic diabetic foot syndrome and advanced chronic kidney disease. Development of individualized treatment strategies with reduced nephrotoxic exposure and safer vascular imaging and revascularization techniques may improve limb preservation and overall clinical outcomes in this high-risk patient population.

## References

1. Armstrong D.G., Swerdlow M.A., Armstrong A.A., Conte M.S., Padula W.V., Bus S.A. Five-year mortality and direct costs of care for people with diabetic foot complications are comparable to cancer // *Journal of Foot and Ankle Research*. 2020. Vol. 13, No. 1. Article ID 16.
2. McDermott K., Fang M., Boulton A.J.M., Selvin E., Hicks C.W. Etiology, epidemiology, and disparities in the burden of diabetic foot ulcers // *Diabetes Care*. 2023. Vol. 46, No. 1. P. 209-221.
3. Prompers L., Huijberts M., Apelqvist J., et al. High prevalence of ischaemia, infection and serious comorbidity in patients with diabetic foot disease in Europe: baseline results from the Eurodiale study // *Diabetologia*. 2007. Vol. 50, No. 1. P. 18-25.
4. Hingorani A., LaMuraglia G.M., Henke P., et al. The management of diabetic foot: a clinical practice guideline by the Society for Vascular Surgery in collaboration with the American Podiatric Medical Association and the Society for Vascular Medicine // *Journal of Vascular Surgery*. 2016. Vol. 63. P. 3S-21S.
5. International Working Group on the Diabetic Foot. IWGDF Guidelines on the prevention and management of diabetic foot disease. The Netherlands: IWGDF, 2023. 112 p.

6. European Society of Cardiology (ESC), European Society for Vascular Surgery (ESVS). ESC Guidelines on the diagnosis and treatment of peripheral arterial diseases // *European Heart Journal*. 2017. Vol. 39, No. 9. P. 763-816.
7. Noronen K., Saarinen E., Alback A., Venermo M. Analysis of the elective treatment process for critical limb ischaemia with tissue loss: diabetic patients require rapid revascularisation // *European Journal of Vascular and Endovascular Surgery*. 2017. Vol. 53, No. 2. P. 206-213.
8. Fujihara M., Kawasaki D., Shintani Y., et al. Safety and feasibility of carbon dioxide angiography during endovascular therapy for patients with chronic kidney disease // *Cardiovascular Intervention and Therapeutics*. 2017. Vol. 32, No. 4. P. 315-320.
9. Gualtieri G., Santoro D., Spinelli F., Mallamaci F., Tripepi G., Zoccali C. Carbon dioxide angiography in patients with critical limb ischemia and advanced chronic kidney disease: safety and efficacy // *Journal of Cardiovascular Medicine*. 2019. Vol. 20, No. 4. P. 282-289.
10. Jiang Y., Ran X., Jia L., et al. Epidemiology of type 2 diabetic foot problems and predictive factors for amputation in China // *International Journal of Lower Extremity Wounds*. 2015. Vol. 14. P. 19-27.
11. Kessel D.O., Patel J.V., Robertson I., et al. Carbon dioxide as a contrast agent in peripheral angiography: current status // *European Radiology*. 2003. Vol. 13, No. 5. P. 1135-1147.
12. Liu Z., Dumville J.C., Hinchliffe R.J., et al. Negative pressure wound therapy for treating foot wounds in people with diabetes mellitus // *Cochrane Database of Systematic Reviews*. 2018. Vol. 10. Article ID CD010318.
13. Monteiro-Soares M., Hamilton E.J., Russell D.A., et al. Classification of foot ulcers in people with diabetes: a systematic review // *Diabetes/Metabolism Research and Reviews*. Published online: 02.05.2023.
14. Ragnarson Tennvall G., Apelqvist J. Health-related quality of life in patients with diabetes mellitus and foot ulcers // *Journal of Diabetes and its Complications*. 2000. Vol. 14, No. 5. P. 235-241.
15. Van Netten J.J., Price P.E., Lavery L.A., et al. Prevention of foot ulcers in the at-risk patient with diabetes: a systematic review // *Diabetes/Metabolism Research and Reviews*. 2016. Vol. 32, Suppl. 1. P. 84-98.
16. Woelfel S., Shin L., Armstrong D.G. Wound care // In: Sidawy M.D.A., Perler M.D.B., eds. *Rutherford's Vascular Surgery and Endovascular Therapy*. 10th ed. Elsevier, 2022.
17. Zeng Z., Dong Y., Hua Q., et al. Computed tomography perfusion study evaluating the curative effect of tibial transverse transport in patients with severe diabetic foot // *Journal of Orthopaedic Translation*. 2019. Vol. 4. P. 5-14.