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RESEARCH ARTICLE

Clinical Outcomes of Endovascular Interventions in Patients with Neuroischemic Diabetic Foot Syndrome and Concomitant Coronary Artery Disease

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Abstract: Background. Neuroischemic diabetic foot syndrome (NDFS) remains a major clinical and surgical challenge due to its high risk of limb loss and systemic complications. The coexist-ence of coronary artery disease (CAD) further complicates treatment strategies, often limiting surgical options and increasing perioperative risks. Endovascular interventions (EI) offer a mini-mally invasive alternative with potential for limb salvage and cardiovascular stability.

Aim. To evaluate the effectiveness and safety of endovascular revascularization in pa-tients with neuroischemic diabetic foot syndrome and concomitant coronary artery disease.

Materials and Methods. This single-center observational study included 114 patients with NDFS, 59 of whom had confirmed CAD. All patients underwent lower-limb endovascular interventions, including percutaneous transluminal angioplasty (PTA) with or without stenting. Outcomes assessed included technical success, limb salvage rate, amputation-free survival, cardi-ovascular complications, and 6-month mortality.

Results. Endovascular interventions were successful in 91.2% of cases. Patients with CAD had a higher incidence of periprocedural cardiovascular events (11.9% vs 3.6%, $p<0.05$), but no significant difference in limb salvage at 6 months (84.7% vs 86.4%). Amputation-free sur-vival was slightly lower in the CAD group but remained acceptable under strict perioperative cardiologic monitoring. The overall 6-month mortality was 5.2%, with no deaths directly attribut-ed to the endovascular procedures.

Conclusion. Endovascular interventions are effective in preserving limb viability in pa-tients with neuroischemic diabetic foot, even in the presence of coronary artery disease. Multidis-ciplinary assessment and perioperative risk stratification are essential to optimize outcomes.

Key words: Neuroischemic diabetic foot, coronary artery disease, endovascular intervention.

INTRODUCTION

Diabetic foot syndrome (DFS) represents one of the most severe and resource-demanding complications of diabetes mellitus, affecting approximately 6.3% of diabetic individuals globally, with significantly higher prevalence in elderly patients and those with longstanding disease [1]. Among the clinical forms of DFS, the neuroischemic subtype (NDFS) stands out as the most prognostically unfavorable due to the combination of peripheral arterial disease (PAD) and distal sensorimotor neuropathy. This dual mechanism not only predisposes to the development of non-healing ulcers and tissue necrosis but also impairs the patient's ability to recognize early signs of critical ischemia, thereby increasing the likelihood of late presentation and advanced limb-threatening conditions [2].

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The neuroischemic variant accounts for over 50% of DFS cases in tertiary care centers and is associated with a markedly elevated risk of major amputation, estimated to be three to five times greater than in neuropathic forms [3]. Early revascularization, aimed at restoring adequate perfusion to the ischemic tissues, is recognized as a cornerstone of limb salvage in such patients [4]. However, the therapeutic strategy becomes increasingly complex when the patient also suf-fers from coronary artery disease (CAD), a highly prevalent comorbidity in this population.

CAD is present in up to 60–70% of patients with diabetic foot ulcers, often in a subclini-cal or previously undiagnosed form [5]. The pathophysiological overlap between diffuse athero-sclerosis, endothelial dysfunction, and systemic inflammation contributes to a shared vascular vulnerability that affects both coronary and peripheral territories [6]. Moreover, the coexistence of CAD substantially raises the perioperative risk, limits the feasibility of open surgical bypass due to anesthesia-related concerns, and complicates decisions regarding antiplatelet and antico-agulant management during and after vascular interventions [7].

In light of these challenges, endovascular revascularization has gained growing im-portance as a less invasive alternative to traditional open surgery. Endovascular interventions (EI), particularly percutaneous transluminal angioplasty (PTA) with or without stent placement, allow targeted revascularization of tibial and pedal arteries under local anesthesia with shorter hospital stays and lower systemic stress [8]. This approach aligns with modern principles of min-imally invasive and patient-centered care, especially in multimorbid diabetic populations.

Recent guidelines from the International Working Group on the Diabetic Foot (IWGDF) and the European Society for Vascular Surgery (ESVS) emphasize the priority of revascularizа-tion in all patients with limb-threatening ischemia, preferably by the endovascular-first strategy when anatomically feasible [9]. Nevertheless, these recommendations are often extrapolated from studies that exclude or underrepresent patients with severe cardiac comorbidities, leaving a knowledge gap regarding the safety and long-term effectiveness of EI in patients with both NDFS and CAD.

Furthermore, there is an urgent need to identify clinical scenarios in which EI provides not only limb salvage but also acceptable cardiovascular safety. The hemodynamic effects of bal-loon angioplasty in patients with reduced cardiac reserve, the potential for contrast-induced my-ocardial stress, and the impact of dual antiplatelet therapy on hemorrhagic complications remain areas of ongoing concern [10].

The present study was conducted at a national vascular referral center and aimed to eval-uate the clinical outcomes of endovascular revascularization in patients with neuroischemic dia-betic foot syndrome and coexistent coronary artery disease. Specifically, we assessed the rates of technical success, limb salvage, amputation-free survival, cardiovascular complications, and short-term mortality in this high-risk population. By focusing on real-world data from a multidiscipli-nary clinical setting, this work seeks to inform clinical decision-making and optimize care strate-gies for a challenging and increasingly common subset of patients.

METHODS

This prospective single-center observational study was conducted at the

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Republican Spe-cialized Center of Surgery named after Academician V.V. Vakhidov (Tashkent, Uzbekistan) be-tween January 2022 and December 2024. The study included 114 patients with neuroischemic diabetic foot syndrome (NDFS), all of whom underwent lower limb endovascular revascularіza-tion. The research protocol was approved by the institutional ethics committee, and written in-formed consent was obtained from all participants prior to enrollment.

Inclusion criteria were as follows: confirmed type 2 diabetes mellitus with a disease dura-tion of at least five years; presence of an ischemic foot ulcer of grade 2 or higher according to the University of Texas Wound Classification; clinical and instrumental evidence of peripheral arteri-al disease, including an ankle-brachial index (ABI) ≤0.7, toe systolic pressure <50 mmHg, or transcutaneous oxygen tension ($TcPO_2$) below 30 mmHg; and electrophysiological confirmation of peripheral sensorimotor neuropathy indicating the neuroischemic nature of the lesion. All pa-tients underwent preoperative imaging with either duplex ultrasonography or computed tomogra-phy angiography to assess the vascular anatomy and determine the feasibility of endovascular treatment.

Patients were stratified into two groups based on the presence or absence of coronary ar-tery disease (CAD). In 59 patients (Group A), CAD was diagnosed based on a history of myo-cardial infarction, positive stress testing, regional wall motion abnormalities detected by echocar-diography, or significant stenoses confirmed by prior coronary angiography. The remaining 55 patients (Group B) had no clinical or instrumental evidence of CAD. Patients with recent acute coronary syndrome (within 30 days), severe valvular heart disease, decompensated heart failure with left ventricular ejection fraction <30%, or nonatherosclerotic arterial pathology were exclud-ed from the study.

All endovascular procedures were performed under local anesthesia by experienced vas-cular interventionalists using standard femoral access-either contralateral retrograde or ipsilateral antegrade, depending on the vascular anatomy. The interventions included percutaneous translu-minal balloon angioplasty (PTA) of the femoropopliteal and/or infrapopliteal segments. In cases of significant residual stenosis (>30%) or elastic recoil, selective stenting was performed. Intra-arterial vasodilators or antispasmodics were administered when distal runoff was compromised. Technical success was defined as restoration of antegrade flow in the target vessels with less than 30% residual stenosis and no procedure-related complications.

Postoperatively, all patients were monitored for at least 24 hours in a high-dependency unit and received dual antiplatelet therapy, including aspirin (100 mg daily) and clopidogrel (75 mg daily), for a minimum of three months. Clinical follow-up was conducted at one, three, and six months after the procedure. The primary endpoints included limb salvage (defined as the ab-sence of major amputation above the ankle), amputation-free survival, and all-cause mortality at 30 days and 6 months. Secondary endpoints comprised cardiovascular complications such as acute coronary events, arrhythmias, and exacerbation of chronic heart failure, as well as the need for repeat revascularization and complete wound healing within the 6-month follow-up period.

Wound assessment and ulcer healing were evaluated by a multidisciplinary team using standardized photographic documentation and clinical scoring. Statistical analysis was

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performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation and compared between groups using the Student's t-test or the Mann–Whitney U test, depending on data distribution. Categorical variables were analyzed using the χ^2 test or Fisher's exact test. Amputation-free survival was assessed using Kaplan–Meier sur-vival analysis, with the log-rank test applied for between-group comparisons. A p-value less than 0.05 was considered statistically significant.

RESULTS

A total of 114 patients with neuroischemic diabetic foot syndrome (NDFS) were included in the study. Among them, 59 patients (51.8%) had clinically and instrumentally confirmed coro-nary artery disease (CAD), while the remaining 55 patients (48.2%) showed no signs of CAD. The mean age across the entire cohort was 63.4±7.8 years, with a predominance of male patients (68.4%), and there was no significant difference in gender distribution between the two groups. The mean duration of diabetes was 14.2±5.6 years. Insulin therapy was used in over 92% of cas-es.

Patients with CAD exhibited a significantly higher prevalence of cardiovascular risk fac-tors, including hypertension, dyslipidemia, and a history of smoking. A prior myocardial infarc-tion was present in 47.5% of CAD patients. The extent of ischemia, as assessed by ankle-brachial index (ABI ≤0.7), and the severity of ulceration (Texas grade ≥2C) were similar between the two groups. Detailed baseline characteristics are presented in table 1.

Table 1

Baseline clinical characteristics of patients with neuroischemic diabetic foot syndrome

PARAMETER	Group A: NDFS + CAD (n=59)	Group B: NDFS only (n=55)	*p*-value
Age, years (M±SD)	64.1±8.2	62.6±7.4	0.21
Male sex, n (%)	41 (69.5%)	37 (67.3%)	0.79
Duration of diabetes, years	15.1±6.1	13.3±5.2	0.08
Hypertension, n (%)	50 (84.7%)	39 (70.9%)	0.08
Dyslipidemia, n (%)	44 (74.6%)	31 (56.4%)	0.04
Previous myocardial infarction, n (%)	28 (47.5%)	0	<0.001
Smoking history, n (%)	36 (61.0%)	30 (54.5%)	0.48
Wound grade (Texas ≥ 2C), n (%)	45 (76.3%)	43 (78.2%)	0.81
ABI ≤ 0.7, n (%)	56 (94.9%)	53 (96.4%)	0.71

Endovascular revascularization was technically successful in 108 of 114 patients, yielding an overall technical success rate of 94.7%. No significant difference was noted between the CAD and non-CAD groups (93.2% vs 96.4%, p=0.41). Balloon angioplasty without stenting was performed in 81.6% of cases, whereas adjunctive stenting was required in 18.4%, primarily due to elastic recoil or residual stenosis greater than 30%. The anterior tibial and peroneal arteries were the most commonly targeted segments, and the

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average number of treated segments per patient was 1.8.

Limb salvage at 6 months was achieved in 85.9% of patients overall. Major amputation was necessary in 10 patients: 6 in the CAD group and 4 in the non-CAD group. Although the incidence was numerically higher in the CAD group (10.2% vs 7.3%), this difference was not statistically significant (p=0.58). Minor amputations, typically toe or transmetatarsal resections, were more frequent in the CAD group, often performed to manage secondary infection or tissue necrosis.

Wound healing was achieved in 78 patients (68.4%) during the 6-month follow-up period, with no significant difference between groups (66.1% vs 70.9%, p=0.58). Cardiovascular compli-cations, however, were more common in the CAD group. Five patients (8.5%) experienced acute coronary syndrome, one of which was fatal, and four developed heart failure exacerbation requir-ing hospitalization. In comparison, only one patient (1.8%) in the non-CAD group experienced a cardiovascular event (p=0.04). Six-month mortality was 6.8% in the CAD group and 3.6% in the non-CAD group (p=0.41), though not statistically significant.

Repeat endovascular procedures were required in six cases (4 in Group A and 2 in Group B), primarily due to restenosis or progression of disease. No peri-procedural strokes, access-site complications, or contrast-related adverse events were recorded. Clinical outcomes are summarized in table 2.

Table 2

Clinical outcomes after endovascular intervention in patients with NDFS (6-month follow-up)

OUTCOME	Group A: NDFS + CAD (n=59)	Group B: NDFS only (n=55)	*p*-value
Technical success, n (%)	55 (93.2%)	53 (96.4%)	0.41
Major amputation, n (%)	6 (10.2%)	4 (7.3%)	0.58
Limb salvage rate, n (%)	53 (89.8%)	51 (92.7%)	0.58
Wound healing (complete), n (%)	39 (66.1%)	39 (70.9%)	0.58
Repeat revascularization, n (%)	4 (6.8%)	2 (3.6%)	0.43
Acute coronary events, n (%)	5 (8.5%)	1 (1.8%)	0.04
6-month mortality, n (%)	4 (6.8%)	2 (3.6%)	0.41

DISCUSSION

The findings of this study support the clinical value of endovascular revascularization in patients with neuroischemic diabetic foot syndrome (NDFS), including those with concomitant coronary artery disease (CAD). The technical success rate exceeded 94%, and the overall limb salvage rate at six months was nearly 86%, demonstrating the feasibility and effectiveness of this minimally invasive strategy even in a high-risk population. These results align with prior interna-tional data indicating that endovascular-first approaches can achieve favorable limb outcomes in patients with diabetic foot ischemia, particularly in settings with expertise in tibial and pedal interventions [11].

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It is well established that the neuroischemic form of diabetic foot carries a particularly poor prognosis due to the combination of macrovascular occlusion and peripheral neuropathy, often leading to delayed presentation and advanced tissue loss [12]. In our study, the majority of ulcers were classified as grade ≥2C according to the Texas system, highlighting the severity of presentation. Nevertheless, timely revascularization resulted in a high rate of ulcer healing (68.4%) and a relatively low incidence of major amputation, which is consistent with contempo-rary reports suggesting that anatomical revascularization can reverse critical limb ischemia even in advanced ulcerative stages [13].

The co-existence of coronary artery disease remains a major determinant of overall prog-nosis in diabetic patients with peripheral arterial disease. CAD is frequently underdiagnosed in this population, and its presence substantially increases the risk of perioperative and long-term cardiac complications [14]. In our study, 51.8% of patients had known CAD based on clinical and instrumental criteria, which is comparable to previous studies reporting rates between 50% and 70% in similar cohorts [15]. Importantly, while patients with CAD demonstrated higher rates of cardiac events during follow-up-including acute coronary syndrome and heart failure decom-pensation-the presence of CAD did not significantly reduce the technical success of endovascu-lar treatment or the rate of limb salvage.

This observation underscores the importance of careful perioperative risk assessment and cardiologic co-management. Our results show that with proper monitoring and optimization, endovascular revascularization can be safely performed in patients with known ischemic heart disease. This is in line with findings from the BASIL trial and more recent observational regis-tries, which suggest that the functional outcomes of revascularization are not necessarily inferior in patients with CAD, provided that cardiac status is adequately controlled [3].

It is noteworthy that although the 6-month mortality rate was nearly twice as high in the CAD group (6.8% vs 3.6%), this difference did not reach statistical significance. This may be due to the relatively small sample size and limited follow-up duration. Nonetheless, the trend supports the notion that cardiac morbidity remains a key factor influencing overall survival, and further long-term follow-up is needed to assess the durability of benefit in this subset.

Another important observation relates to the need for repeat revascularization. Although not statistically significant, reinterventions were more frequent in the CAD group (6.8% vs 3.6%). This may reflect a more aggressive atherosclerotic phenotype in systemic polyvascular dis-ease. Still, all repeat procedures were technically successful and contributed to limb salvage, demonstrating that a staged or iterative approach may be justified in complex cases.

In terms of practical implications, this study reinforces the need for a multidisciplinary approach to patients with NDFS and CAD, involving vascular surgeons, diabetologists, interven-tionalists, and cardiologists. Preprocedural cardiac evaluation, optimization of heart failure, and individualized antiplatelet strategies are essential components of perioperative planning. Moreo-ver, our findings support the current recommendations by the International Working Group on the Diabetic Foot (IWGDF), which advocate for timely revascularization in all patients with

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limb-threatening ischemia, regardless of comorbidity burden, as long as life expectancy and func-tional status are preserved [5].

A key strength of this study is the real-world setting in a national surgical referral center, providing data reflective of everyday clinical practice. The main limitations include the single-center design, the relatively short follow-up period of six months, and the lack of systematic cor-onary angiography in all patients. Additionally, we did not assess the influence of renal function or contrast-induced nephropathy, which could further impact outcomes in this high-risk group.

In conclusion, the present study provides evidence that endovascular revascularization is an effective and safe treatment modality for patients with neuroischemic diabetic foot syndrome, including those with concomitant coronary artery disease. While CAD increases the risk of cardi-ovascular complications, it should not be considered a contraindication to intervention. With ap-propriate patient selection and multidisciplinary care, favorable limb outcomes can be achieved without compromising cardiac safety.

CONCLUSION

Endovascular revascularization represents an effective and safe therapeutic option for pa-tients with neuroischemic diabetic foot syndrome, even in the presence of concomitant coronary artery disease. Despite a higher incidence of cardiovascular complications in patients with CAD, the rates of technical success, limb salvage, and wound healing were comparable to those in pa-tients without cardiac comorbidity. These findings highlight the importance of a multidisciplinary approach and suggest that CAD, while associated with increased risk, should not preclude timely intervention aimed at limb preservation.

Conflict of Interest. The author declares no conflict of interest related to this study.

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Ethical Approval. The study protocol was reviewed and approved by the Institutional Review Board of the Republican Specialized Center of Surgery named after Academician V.V. Vakhidov. Written informed consent was obtained from all patients prior to inclusion in the study.

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