FREE SURVIVAL FOLLOWING ENDOVASCULAR INTERVENTION

Hr. Georgiev[1], Kr. Yordanova[1], Y. Stefanova[1], N. Kolev[2]

[1]Department of Vascular Surgery, UMHAT Medica, Ruse
[2]Clinic of Vascular Surgery, Military Medical Academy, Sofia

Средносрочна преживяемост и преживяемост без ампутация след ендоваскуларна интервенция

Хр. Георгиев[1], Кр. Йорданова[1], Й. Стефанова[1], Н. Колев[2]

[1]Отделение по съдова хирургия, УМБАЛ „Медика Русе“
[2]Клиника по съдова хирургия, ВМА, София

Abstract:

Chronic limb-threatening ischemia (CLTI) is associated with a high risk of amputation and mortality, while the effectiveness of infrapopliteal endovascular revascularization remains a subject of debate. The aim of this study was to evaluate clinical outcomes following endovascular recanalization in patients with limb-threatening ischemia. A total of 136 patients were followed over a 12-month period. Endpoints included overall survival, amputation-free survival, primary and assisted primary patency, and rates of restenosis and reintervention. The one-year survival rate was 89.0%, and the amputation-free survival rate was 88.6%. Limb salvage was achieved in 94.6% of patients. Primary patency was 57.6%, and assisted primary patency was 61.3%. Restenosis was observed in 36% of cases, and reinterventions were required in 26.2%. Independent predictors of adverse outcomes included age over 80 years, chronic kidney disease, congestive heart failure, TASC D lesions, and the inability to perform surgical bypass. Endovascular revascularization provides high rates of limb salvage despite moderate patency and a significant incidence of restenosis.

Key words:

chronic limb-threatening ischemia; peripheral arterial disease; critical ischemia; digital subtraction angiography; congestive heart failure; chronic kidney disease; acute myocardial infarction

Address for correspondence:

Dr Hristo Georgiev, e-mail: hristo_geor@abv.bg

Резюме:

Хроничната критична исхемия на крайника е свързана с висок риск от ампутация и смъртност, като ефективността на инфрапоплитеалната ендоваскуларна реваскуларизация остава предмет на дискусия. Целта на проучването е да се оценят клиничните резултати след ендоваскуларна реканализация при пациенти с критична исхемия, застрашаваща крайника. Проследени са 136 пациенти за период от 12 месеца, като са анализирани преживяемост, преживяемост без ампутация, първична и асистирана проходимост, честота на рестенози и реинтервенции. Едногодишната преживяемост е 89,0%, а преживяемостта без ампутация – 88,6%. Запазване на крайника е постигнато при 94,6% от пациентите. Първичната проходимост е 57,6%, а асистираната – 61,3%. Рестенози са установени при 36% от случаите, а реинтервенции – при 26,2%. Независими предиктори за неблагоприятен изход са възраст над 80 години, хронична бъбречна и сърдечна недостатъчност, TASC D лезии и липса на възможност за байпас. Ендоваскуларната реваскуларизация осигурява висока честота на запазване на крайника, въпреки умерена проходимост и значима честота на рестенози.

Ключови думи:

хронична критична исхемия на крайника, периферна артериална болест, критична исхемия, сърдечна недостатъчност, хронична бъбречна недостатъчност, карцином, исхемичен мозъчен инсулт

Адрес за кореспонденция:

Д-р Христо Георгиев, e-mail: hristo_geor@abv.bg

Introduction

Currently, there is insufficient high-quality evidence regarding the effectiveness of infrapopliteal revascularization with respect to mid-term survival and amputation-free survival. A systematic review analyzing randomized and observational studies conducted between 2003 and 2017 found higher rates of cardiovascular death, myocardial infarction, stroke, and major amputation in patients with peripheral arterial disease (PAD) [1]. It was also established that patients with critical ischemia (CI) are at the highest risk of limb loss.

Pharmacological therapy alone cannot reliably guarantee limb salvage in patients with chronic limb-threatening ischemia (CLTI). The principal therapeutic strategies remain surgical and endovascular revascularization.

Infrapopliteal lesions in this patient population are frequently long, heavily calcified, and occlusive in nature, which significantly complicates technical success and limits the potential for collateral network development. These factors contribute to higher rates of major amputation and mortality.

Aim

The primary aim of this study was to evaluate clinical outcomes following endovascular recanalization in patients with critical limb-threatening ischemia (CLTI), with specific focus on limb salvage rates and the incidence of major amputations within 12 months of the procedure.

Secondary aims included comparison of one-year patency rates according to the TASC classification of lesions, and assessment of wound healing time following direct versus indirect revascularization.

Materials and methods

The study population comprised patients with critical limb-threatening ischemia. Pre-procedural evaluation of the lower limb arteries was performed using duplex ultrasonography and digital subtraction angiography (DSA).

A 12-month clinical and imaging follow-up was conducted, evaluating primary patency, the need for reinterventions, overall survival, amputation rates, and wound healing. Complete follow-up data over the 12-month period were obtained for 136 patients, with a median follow-up duration of 292 days after endovascular intervention.

The analysis was based on assessments of limb salvage, amputation-free survival, and wound healing. Statistical analysis was performed using IBM SPSS Statistics, version 31.0.1.0. The significance level was set at $\alpha = 0.05$, and the null hypothesis was rejected at $p < 0.05$. Analytical methods included the non-parametric Kruskal–Wallis test for comparisons between more than two independent groups, Kaplan–Meier analysis for evaluation of survival and cumulative patency, and the log-rank test for between-group survival comparisons.

Results

Complete 12-month follow-up was achieved for all 136 patients. The median follow-up duration after endovascular intervention was 292 days (interquartile range: 136–727 days). During the follow-up period, 15 patients (11.0%) died. The cause of death was unknown in 4 patients; the remaining deaths were attributable to congestive heart failure (n = 5), chronic kidney disease requiring dialysis (n = 4), malignancy (n = 2), and ischemic stroke (n = 2).

Published data indicate a cumulative survival of approximately 79% in patients with critical ischemia. The most common causes of death are related to systemic vascular disease, reflecting the high burden of comorbidities in this patient population. Cardiovascular complications – including myocardial infarction and stroke – represent the leading causes of mortality, rather than local limb pathology.

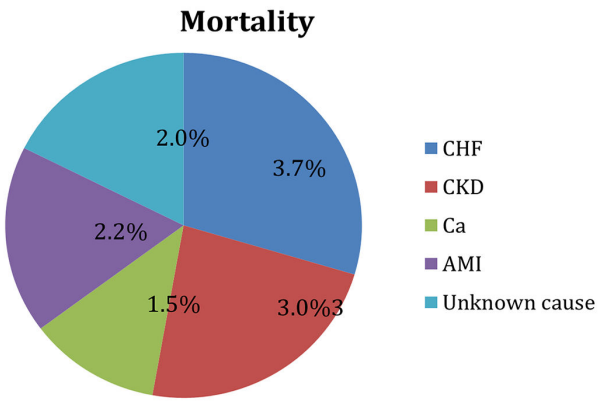

Fig. 1. Causes of death in patients with CLTI

The one-year overall survival in the study cohort was 89.0%, with a mean survival time of 11.3 months (95% CI: 10.9–11.7 months). Logistic binomial regression analysis identified coronary artery disease and age over 80 years as the primary predictors of mortality.

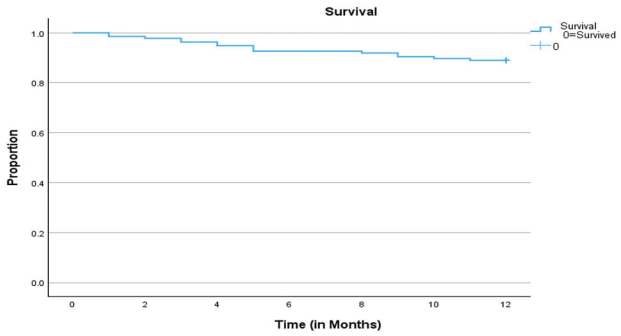

Fig. 2 Cumulative survival – standard error <10%

Multivariable Cox regression analysis confirmed the following independent risk factors for mortality: age > 80 years (HR 2.64; 95% CI: 1.60-4.36; p < 0.001), chronic kidney disease (HR 1.71; 95% CI: 1.04–2.86; p = 0.039), congestive heart failure (HR 1.46; 95% CI: 1.02–2.07; p = 0.041), and the inability to perform surgical bypass, which was identified as the strongest predictor (HR 13.3; 95% CI: 6.6-27.4; p < 0.001).

Table 1. Multivariable Cox regression analysis of 1-year survival risk after intervention

Predictors	HR	CI9%	P
> 80 age	2,64	1.60-4.36	< 0.001
CKD	1.71	1.04-2.86	0.039
CHF	1.46	1.02-2.07	0.041
Patient unsuitable for bypass	13,3	6,6-27,4	0,001

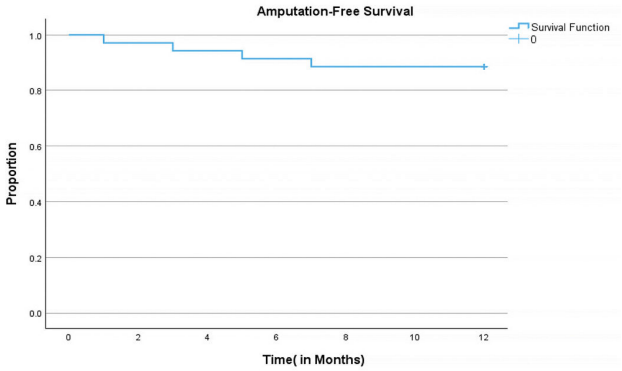

Fig. 3. Kaplan-Meier (KM) – amputation-free survival

Kaplan–Meier analysis demonstrated an amputation-free survival of 88.6% at one year following endovascular therapy. The 30-day major amputation rate was 1.4%. All patients who underwent amputation had poorly controlled diabetes mellitus; one patient presented with gangrene and the remainder with non-healing wounds and significant comorbidities.

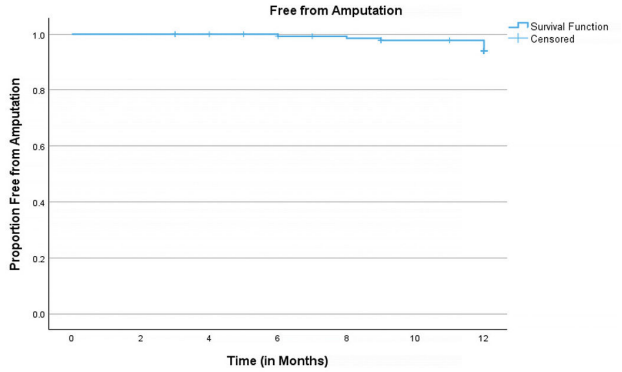

Fig. 4. Amputation-free survival – standard error <10%

Limb salvage was achieved in 94.6% of patients, defined as freedom from major amputation at 12 months. All amputations occurred within the first year, with the highest incidence observed at six months. Limb salvage rates were inversely correlated with TASC lesion complexity: seven amputations occurred in TASC D lesions, yielding a one-year limb salvage rate of 87.5% for TASC D versus 98% for TASC C, with no amputations recorded in TASC A or B lesions. Multivariable Cox regression analysis identified TASC D lesions (HR 2.75; 95% CI: 1.13–12.46; p = 0.031) and the inability to perform surgical bypass (HR 2.91; 95% CI: 1.61–5.12; p < 0.001) as independent predictors of major amputation.

Table 2. Multivariable Cox regression analysis of the risk of amputation at 1 year after intervention

Predictors		Amputation	
	HR	(95% CI)	P стойнст
Age > 80	1.55	1.30-1.85	0.05
Dialysis	1.22	1.17-1.30	0.01
CHF	1.44	1.12-1.79	0.03
Dyslipidemia	0.75	0.71-0.84	0.01
Diabetes	1.04	1.13-12.59	0.04
TASC D	2.75	1.00-109	0.31
Unsuitable for bypass	2.91	1.61-5.12	0.001
Current smoker	1.07(0.98-1.16)		0.04

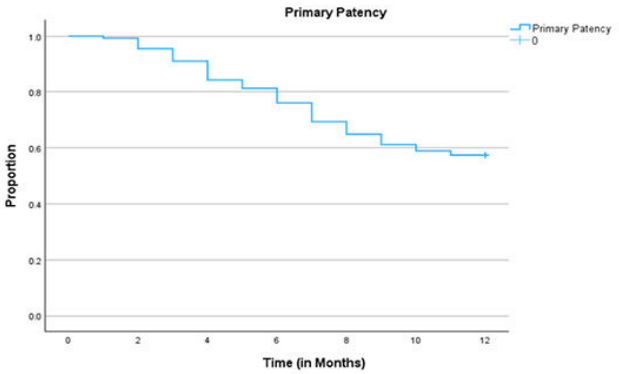

Fig. 5 Primary patency rates, defined according to conventional criteria. Standard error (SE) <10%

Primary patency – defined as vessel patency without the need for reintervention – was 57.6% at 12 months. The Kaplan-Meier curve demonstrated a marked decline in primary patency between the 7th and 9th months following percutaneous transluminal angioplasty. The mean duration of maintained patency was 9.4 months (95% CI: 8.8-10.0 months). Patency rates varied significantly according to TASC classification: 60% for TASC A, 64% for TASC B, 51% for TASC C, and 48% for TASC D (p < 0.001), underscoring the importance of active surveillance beyond the sixth postoperative month.

Assisted primary patency, achieved through endovascular reintervention for restenosis, was 61.3% at 12 months. Loss of patency occurred predominantly around the tenth month, with a mean patency duration of 9.46 months (95% CI: 8.88-10.05 months).

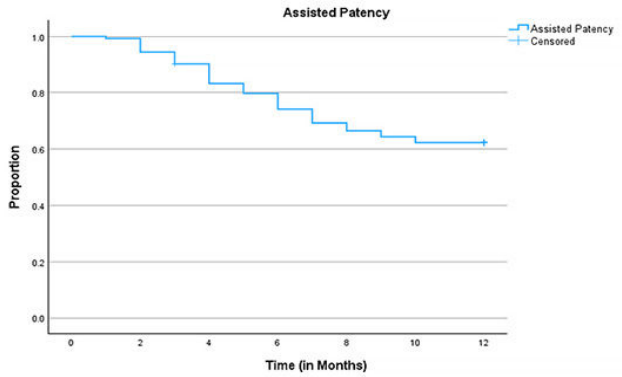

Fig. 6. Assisted patency

During follow-up, restenosis was absent in 64% of patients, while it was documented in 36%. The peak incidence of restenosis occurred between the third and eighth months. A statistically significant association was observed between the degree of restenosis and TASC classification: restenosis rates were 20.0% for TASC A, 18.1% for TASC B, 35.4% for TASC C, and 46.1% for TASC D (p = 0.018). TASC D lesions were also associated with earlier onset of restenosis.

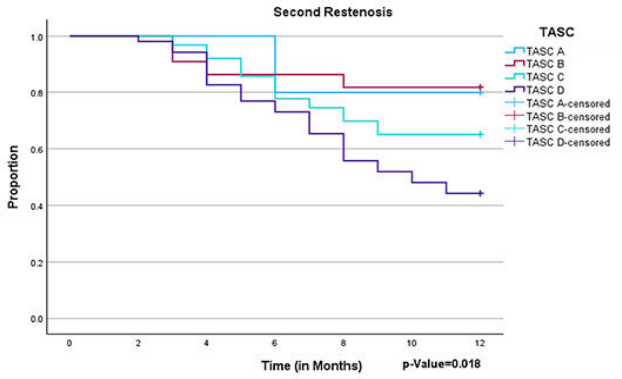

Fig. 7. No secondary restenosis according to the TransAtlantic Inter-Society Consensus (TASC) classification

Univariate analysis identified the following predictors of restenosis: critical ischemia as classified by Rutherford grades 4-6, tibial artery intervention, occlusive lesions, and TASC D classification. On multivariate analysis, independent predictors of restenosis were critical ischemia (p = 0.041), occlusive lesions (p = 0.031), and TASC D lesions (p = 0.001).

Table 3. Predictors of restenosis identified by univariate analysis

Predictor	HR	95% CI	P
Rutherford 6	1.357	1.037–5.360	0.005
TASC D	1.476	0.188–0.929	p = 0,001
Occlusive lesions	2.437	1.111–5.345	0.011

Reintervention was required in 37 patients (27.2%) during the follow-up period. The most common indications included recurrent rest pain, Doppler-confirmed restenosis, and non-healing wounds. The mean time to reintervention was 9 to 11 months, with risk concentrated between the sixth and twelfth months. In 78.4% of reintervention cases, restenosis involved the originally treated vessel; in the remaining 21.6%, disease progression had affected a previously untreated vessel.

Table 4. Indications for reintervention

Indications for reintervention	
Non-healing wound	6 (16.2%)
Doppler evidence of restenosis	14(39,6%)
Recurrent rest pain	17(46,4%)

The most frequently retreated vessels were the anterior tibial artery (21.6%), superficial femoral artery (18.9%), and popliteal artery (16.2%), followed by the posterior tibial artery (16.1%), the tibioperoneal trunk (11.5%), and the peroneal artery (5.1%).

Reinterventions were performed at single or multiple levels; some patients required combined treatment encompassing femoral or popliteal procedures in addition to tibial interventions. Surgical bypass was performed in three patients.

Table 5. Baseline characteristics of the total population, the reintervention group, and the non-reintervention group

	Total	Reintervention YES	Reintervention NO	P
Men	69,3%	47%	53,5%	0,64
Women	30,9%	46%	69%%	0,002
Diabetes	39,2%	54,5%	45,4%	0,52
Hypertension	42%	51,5%	49	
Dyslipidemia	43%	55%	45%	0,21
Dialysis	33%	64%	36%	0,001
CHF	79%	45,4%	36,3%	0,031
Smoker	73%	39,3%	33,3%	0,82
Wounds	25,5%	36%	48%	0,02

Discussion

Complete 12-month follow-up was achieved for all 136 patients, with a median follow-up duration of 292 days after endovascular intervention. Fifteen patients (11.0%) died during the follow-up period. Causes of death included unknown etiology (n = 4), congestive heart failure (n = 5), chronic kidney disease requiring dialysis (n = 4), malignancy (n = 2), and ischemic stroke (n = 2).

Published data report cumulative survival rates of approximately 79% in patients with critical ischemia. The predominant causes of mortality are related to systemic vascular disease, reflecting the high comorbidity burden characteristic of this patient population.

Cardiovascular complications – namely myocardial infarction and stroke – are the leading contributors to mortality, rather than the local limb disease itself.

The mean wound healing time was 109 days in patients who underwent direct revascularization, compared with 318 days in those who underwent indirect revascularization. The 95% confidence intervals confirm that wound healing is significantly faster following direct revascularization.

Wound healing was defined as complete epithelialization of the index ulcer or the stump following a minor amputation. Wound care, including surgical debridement where necessary, was initiated prior to endovascular intervention and was systematically monitored during hospitalization and at each subsequent outpatient visit. Poor wound healing was defined as lack of improvement within four weeks after revascularization, documented deterioration or wound enlargement at the last follow-up visit, or progression to major amputation. In general, patients with deteriorating wounds but viable limbs underwent repeat revascularization. In the study cohort, five patients required reintervention: two in the direct revascularization group and three in the indirect revascularization group. Despite reintervention, three patients ultimately required major amputation. In cases of infection and inflammatory signs, systemic and local antibiotic therapy were administered; once the infection was controlled, routine wound care was resumed.

Conclusion

Limb salvage was achieved in 94.6% of patients, with no major amputations recorded within the first 12 months following the procedure. All amputations occurred within the first year, with the highest incidence at six months.

A significant correlation was observed between limb salvage rates and TASC lesion classification, with the majority of amputations occurring in patients with more complex lesions (TASC D).

The mean time to wound healing was significantly shorter following direct revascularization compared to indirect revascularization (109 days versus 318 days), underscoring the clinical superiority of the direct revascularization approach in this patient group.

References

1. Norgren L, Hiatt WR, Dormandy JA, et al. Inter-Society Consensus for the Management of Peripheral Arterial Disease (TASC II). J Vasc Surg. 2007;45(Suppl S):S5–S67.
2. Jamieson C. The definition of critical ischaemia of a limb. Br J Surg. 1982;69(Suppl):S1–S2.
3. Ad Hoc Committee on Reporting Standards, Society for Vascular Surgery/North American Chapter, International Society for Cardiovascular Surgery. Suggested standards for reports dealing with lower extremity ischemia. J Vasc Surg. 1986;4(1):80–94.
4. Rutherford RB, Baker JD, Ernst C, et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. J Vasc Surg. 1997;26(3):517–538.
5. Dormandy JA, Rutherford RB; TASC Working Group. Management of peripheral arterial disease (PAD). J Vasc Surg. 2000;31(1 Pt 2):S1–S296.
6. Abu Dabrh AM, Steffen MW, Undavalli C, et al. The natural history of untreated severe or critical limb ischemia. J Vasc Surg. 2015;62(6):1642–1651.e3.
7. Spreen MI, Martens JM, Knippenberg B, et al. High and immeasurable ankle-brachial index as predictor of poor amputation-free survival in critical limb ischemia. J Vasc Surg. 2018;67(1):157–165.
8. Bird CE, Criqui MH, Fronek A, et al. Quantitative and qualitative progression of peripheral arterial disease by non-invasive testing. Vasc Med. 1999;4(1):15–21.
9. Fowkes FG, Lowe GD, Housley E, et al. Cross-linked fibrin degradation products, progression of peripheral arterial disease, and risk of coronary heart disease. Lancet. 1993;342(8881):84–88.
10. Kennedy M, Solomon C, Manolio TA, et al. Risk factors for declining ankle-brachial index in men and women 65 years or older: the Cardiovascular Health Study. Arch Intern Med. 2005;165(16):1896–1902.
11. Valentine RJ, Hansen ME, Myers SI, et al. Intermittent claudication caused by atherosclerosis in patients aged forty years and younger. Surgery. 1990;107(5):560–565.
12. Levy PJ, Gonzalez MF, Hornung CA, et al. A prospective evaluation of atherosclerotic risk factors and hypercoagulability in young adults with premature lower extremity atherosclerosis. J Vasc Surg. 1996;23(1):36–45.

Received 9 March 2026