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Research paper

Acute limb ischemia and its predictive factors after revascularization: A single-center retrospective study from a resource-limited setting

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ABSTRACT

Background: Patients with acute limb ischemia (ALI) are being treated using both open and endovascular procedures, with technological developments making treatments simpler and safer. However, the most significant improvements in outcomes for these patients will come from timely diagnosis, followed by quick and standardized therapy to reduce the likelihood of limb loss and subsequent sequels. The study sought to explore the clinical presentation and treatment outcome of open surgical revascularization for ALI in a resource-limited setting.

Method: Between June 2019 and December 2022, a retrospective study including all patients presenting with ALI and treated with urgent revascularization at Al-Thora General Hospital, Sana'a, Yemen, was performed. All patients were classified using Rutherford's ALI categorization. Demographic parameters, clinical data, treatment details, and outcomes were obtained from patient medical profiles. The main outcome was organ/patient survival and amputation 30 days following surgery. Secondary outcomes included factors associated with amputation.

Result: Overall, 91 ALI patients were treated with urgent open revascularization during the study period. The mean age of patients was 55.9 ± 11.5 years, and most cases (61.5%) were male patients. The duration of symptoms was longer than 36 h in 29 cases (31.9%). Comorbidities such as ischemic heart disease, hypertension, diabetes mellitus, hyperlipidemia, cerebrovascular disease, congestive heart failure, renal impairment, atrial fibrillation, and history of malignancy were present in 61 (67.0%), 76 (83.5%), 56 (61.5%), 49 (53.8%), 11 (12.1%), 21 (23.1%), 25 (27.5%), 47 (51.6%), and 8 (8.8%) cases, respectively. Sensory impairment was seen in 30 (33.0%) cases. Thrombosis etiology was the most common ALI causes (80.2%). In laboratory results, high C-reactive protein (CRP) levels, low hemoglobin levels (anemia), and low albumin levels were present in 15 (16.5%), 15 (16.5%), and 8 (8.8%), respectively. Most ALI (85.7%) were occurred in lower extremity. Additionally, 61 (67.0%)

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cases were in the Rutherford IIb stages. All cases were undergoing open surgical revascularization and fasciotomy was made in 6 (6.6%) cases. The amputation-free survival rate was 76.9% at 30 days follow-up. The 30-day outcome was amputation in 21 (23.1%) cases and death in one case. In univariate analysis, current smoking, history of diabetes, hemodialysis, history of malignancy, atrial fibrillation, sensory impairment, prolonged symptoms duration (>36 h), elevated CRP (>5 mg/L), advanced ALI stage (Rutherford's class IIb), fasciotomy, and thrombosis etiology were associated with revascularization failure and amputation and were statistically significant (all *p*-values < 0.05). **Conclusion:** In this study, despite no endovascular treatment offered, the application of the standard treatment—open surgical revascularization—in patients with ALI represents the key to success for limb salvage with acceptable amputation rates even in a resource-limited setting. Additionally, independent risk factors for amputation were current smoking, history of diabetes, hemodialysis, history of malignancy, atrial fibrillation, sensory impairment, prolonged symptoms duration (>36 h), elevated CRP (>5 mg/L), advanced ALI stage, fasciotomy, and thrombosis etiology. Advanced tailoring revascularization strategy and timing for the proper patient and comorbidities treatment could potentially improve amputation-free survival in ALI patients. Future studies should incorporate both limb severity and anatomic staging to best guide clinical decision-making in ALI.

Keywords: acute limb ischemia, revascularization, outcome, amputation-free survival, predictive factor

INTRODUCTION

Acute arterial occlusion, which is also known as acute limb ischemia (ALI), is a vascular emergency characterized by a sudden loss of blood flow to the extremities within 2 weeks of an inciting event, usually associated with atrial fibrillation, underlying hypercoagulable or occlusive conditions.[1] The occurrence of ALI is estimated at 10–14 cases per 100,000 people annually and is predominantly observed in the lower extremities.[2,3] ALI due to *in situ* thrombosis, arterial embolization, or bypass graft thrombosis remains a challenge to effective treatment with historically high rates of amputation rate (12–50%) and mortality (20–40%), depending on the condition disease severity and time to revascularization.[2,3] Previous studies have indicated that patients with ALI have amputation and fatality rates ranging from 14.3% to 30% and 11.4% to 28.9%, respectively.[4]

The clinical manifestation and symptoms of ALI depend on the particular artery affected. At initial presentation, the severity of ALI is categorized according to the Rutherford classification, which classifies a limb as not immediately threatened (Class 1), marginally threatened (class IIa), immediately threatened (class IIb), or irreversibly threatened defined as non-viable (class 3).[5] Previous studies have confirmed the usefulness of the Rutherford classification as a risk stratification tool, with higher classes being associated with higher rates of limb loss.[6] Other factors associated with amputation include increasing age and longer preoperative ischemic times.[2,5]

Due to the heterogeneity of the disease, the abundance of treatment options, and the limited availability of randomized clinical trials (RCTs) and modern real-world data, the outcome of ALI and optimal treatment options are still inconclusive.[2,3,5] Traditionally, open surgical procedures such as embolectomy and bypass surgery have been the treatment of choice; However, in recent years, an increasing number of endovascular procedures have been performed in many institutions, including aspiration/rotational thrombectomy, catheter-directed thrombolysis, and transluminal angioplasty with or without stenting.[7] A recent systemic review also showed no difference in outcome between thrombolysis and surgical treatment in ALI cases.[8] In Yemen, no published study has highlighted the ALI problem and its consequences. The study sought to explore the clinical presentation, treatment, and results of open surgical revascularization for ALI in a resource-limited setting.

MATERIALS AND METHODS

Study Setting and Design

A single-center retrospective study was conducted including all patients with ALI treated with urgent open revascularization (open thromboembolectomy or endarterectomy) between June 2019 and December 2022 at Al-Thora General Hospital, Sana'a, Yemen. The study protocol was prepared by the principles of the Declaration of Helsinki and approved by the Ethics Committee of Al-Thora General Hospital (Sana'a, Yemen) (ID: 2343, on 05/02/2024). Due to the anonymous retrospective nature of the study, written informed consent from the included patients was not required. ALI was defined as a sudden onset of circulatory deficiency in the upper or lower extremities that endangers their viability and does not last longer than 14 days.[3]

Inclusion Criteria

All consecutive patients, who presented to the vascular service of the Institute of Emergency Medicine (Sana'a, Yemen), were diagnosed with ALI, and were treated with urgent open revascularization, were enrolled. Patients with acute occlusion of native arteries, vascular reconstructions (autologous conduit, synthetic bypass, stent, or stent graft), and peripheral aneurysms were included.

Exclusion Criteria

Patients were excluded if they met any of the following criteria: (1) ALI caused by trauma (including iatrogenic injuries); (2) ALI associated with aortic dissection; (3) ALI as a complication of vascular interventions developed in the early postoperative period (during the same hospitalization); and (4) acute onset of intermittent claudication.

Diagnosis and Treatment

Diagnosis of ALI was made clinically by a qualified vascular surgeon and the severity of ischemia was classified according to the Rutherford categories: grade I—rest pain without sensory loss and motor deficit; grade IIa—sensory loss without motor deficit, and grade IIb—any motor deficit.[6] Duplex ultrasound (DUS), computed tomography (CT) angiography, and digital subtraction angiography were used at the discretion of specialists and depending on availability. Direct pressure measurement in extremity compartments was performed in patients with clinically suspected compartment syndrome. Surgical risk was stratified according to the definitions of the American Society of Anesthesiologists (ASA) classification. Open surgical procedures (thrombo-embolectomy, thrombo-endarterectomy, and bypass) were mostly used for limb revascularization based on the Rutherford classification.[7] All patients received antithrombotic treatment perioperatively, while the selection of drugs, dose, and duration of therapy was done individually. Internal medicine specialists and intensivists were responsible for the postoperative treatment according to the protocols available at that time.

Data Gathering

Demographic characteristics (age, sex), duration of symptoms, ASA class, smoking status, and comorbidities (e.g., ischemic heart disease, hypertension, diabetes mellitus, hyperlipidemia, cerebrovascular disease, congestive heart failure, renal impairment, atrial fibrillation, and history of malignancy), clinical, imaging, and laboratory data relevant to the diagnosis and severity of ALI (e.g., low hemoglobin level, high C-reactive protein (CRP), and low albumin level, ALI class according to the Rutherford categories, extremity involved, and artery involved), details of revascularization procedure, and postoperative outcome (e.g., amputation, success, and death), length of follow-up time, and complications were collected from the patient's medical profiles. The high CRP levels were defined as CRP >5 mg/L, low hemoglobin levels (anemia) were defined as <12 mg/dL, and low albumin levels were defined as albumin <3.4 g/dL. The postoperative complications were categorized into systemic and local complications. Systemic complications include respiratory, renal, rhabdomyolysis, and cardiovascular complications, whereas local complications include surgical site infection (SSI), seroma/lymphatic fistula, re-occlusion, and bleeding.

Study Outcomes

The main outcome was organ/patient survival and amputation and/or mortality 30 days following surgery. Secondary outcomes included perioperative factors associated with amputation outcomes.

Statistical Analysis

Frequencies and percentages were used to describe the categorical variables, and means ± standard deviation was used to describe the numerical variables. The Smirnov–Kolmogorov test was used to determine normality. The significance of the variables' correlations with postoperative amputation in the study population was determined using Fisher's exact test or chi-square analysis. A p-value less than 0.05 was defined as a statistically significant p-value. The IBM SPSS software (version 22, IBM Corp., Armonk, New York) was used for statistical analysis in the study.

RESULTS

Overall, 91 patients were treated with urgent open revascularization during the study period. The mean age of patients was 55.9 ± 11.5 years (range 35–79 years), and most cases (61.5%) were male.

The duration of symptoms was less than 36 h in 62 cases (68.1%), whereas it was longer than 36 h in 29 cases (31.9%). Current smoking was present in 45 patients (49.5%). Comorbidities such as ischemic heart disease, hypertension, diabetes mellitus, hyperlipidemia, cerebrovascular disease, congestive heart failure, renal impairment, atrial fibrillation, and history of malignancy were present in 61 (67.0%), 76 (83.5%), 56 (61.5%), 49 (53.8%), 11 (12.1%), 21 (23.1%), 25 (27.5%), 47 (51.6%), and 8 (8.8%) cases, respectively. Sensory impairment was observed in 30 cases (33.0%). Demographic characteristics of participants are shown in Table 1.

Table 1. Demographic characteristics of participants.

Variables	N (%)
Age (years), Mean ± SD	55.9 ± 11.5 (range 35–79)
Sex	
Male	56 (61.5%)
Female	35 (38.5%)
Duration	
≤36 h	62 (68.1%)
>36 h	29 (31.9%)
Smoking	45 (49.5%)
Comorbidities	
Ischemic heart disease	61 (67.0%)
Hypertension	76 (83.5%)
Diabetes	56 (61.5%)
Hyperlipidemia	49 (53.8%)
Cerebrovascular disease	11 (12.1%)
Congestive heart failure	21 (23.1%)
Hemodialysis	25 (27.5%)
Atrial fibrillation	47 (51.6%)
History of malignancy	8 (8.8%)
Laboratory data	
Elevated CRP	15 (16.5%)
Anemia	15 (16.5%)
Low albumin	8 (8.8%)
Sensory impairment	30 (33.0%)
Acute limb ischemia cases	
Thrombosis	73 (80.2%)
Arterial embolization	18 (19.8%)
ALI stage according to Rutherford's classification	
Rutherford I	8 (8.8%)
Rutherford IIa	15 (16.5%)
Rutherford IIb	61 (67.0%)
Rutherford III	7 (7.7%)
ASA classification	
ASA I/I	19 (20.9%)
ASA III	58 (63.7%)
ASA IV/V	14 (15.4%)
Extremity involved	
Lower extremity	78 (85.7%)
Upper extremity	13 (14.3%)
Fasciotomy	6 (6.6%)
Involved arteries	
Superficial femoral artery	40 (44.0%)
External iliac artery	10 (11.0%)
Popliteal artery	28 (30.8%)
Brachial artery	13 (14.3%)

Abbreviations: ASA, American Society of Anesthesiologists; ALI, acute limb ischemia; CRP, C-reactive protein.

Table 2. Management outcome and postoperative complications of acute limb ischemia cases.

Variables	N (%)
Systemic complication	21 (23.1%)
Respiratory complications	12 (13.2%)
Renal complications	5 (5.5%)
Cardiovascular complications	5 (5.5%)
Rhabdomyolysis	5 (5.5%)
Local Complications	18 (19.8%)
Surgical site infection	9 (9.9%)
Seroma/lymphatic fistula	3 (3.3%)
Re-occlusion	4 (4.4%)
Bleeding	2 (2.2%)
Hospitalization (day), Mean ±SD	8.8 ± 3.2 (range 3–17)
Outcome	
Death	1 (1.1%)
Amputation	21 (23.1%)

Thrombosis etiology was the most common ALI causes (80.2%). In laboratory results, high CRP levels (›5 mg/L), low hemoglobin levels (anemia; ‹12 mg/dl), and low albumin levels (‹3.4 g/dL) were present in 15 (16.5%),15 (16.5%), and 8 (8.8%) cases, respectively. Most ALI cases (85.7%) were occurred in lower limbs. The commonly involved artery was the superficial femoral artery (44.0%). Additionally, 61 (67.0%) were in the Rutherford IIb stage. All ALI cases were undergoing open surgical revascularization [open thromboembolectomy in 73 (80.2%) cases or endarterectomy in 18 (19.8%) cases] and fasciotomy was made in 6 (6.6%) cases. The median duration of surgery was 70 min (IQR: 55–111 min). The mean hospital stay was 8.8 ±3.2 days (range 3–17 days). The systemic complications occurred in 21 (23.1%) patients and were respiratory in 12 (13.2%), renal in 5 (5.5%), cardiovascular in 5 (5.5%), and rhabdomyolysis in 5 cases (5.5%). Local complication was presented in 18 (19.8%), and SSI was the most common local complication (9.9%) (Table 2).

The outcome of the intervention was successful in 70 (76.9%). With 30 days of follow-up, amputation was needed in 21 cases (23.1%) and one case (1.1%) died postoperatively (All amputations were major and performed above the knee). The amputation-free survival rate was 76.9% at 1-month follow-up. All open thromboembolectomy or endarterectomy failed cases underwent bypass. However, all bypass surgeries were failed.

Factors Associated With Amputation

In univariate analysis, current smoking, history of diabetes, hemodialysis, history of malignancy, atrial fibrillation, sensory impairment, prolonged symptoms duration (≥36 h), elevated CRP (›5 mg/L), advanced ALI stage (Rutherford's class IIb), fasciotomy, and thrombosis etiology were associated with revascularization failure and postoperative amputation and were statistically significant (all p-values ‹ 0.05) (Table 3).

DISCUSSION

In this study, we reported the clinical presentation and treatment outcome of open surgical revascularization for ALI in a resource-limited setting. Our result showed that the amputation-free survival rate was 76.9% at 1-month follow-up. Additionally, our result showed that current smoking, history of diabetes, hemodialysis, history of malignancy, atrial fibrillation, sensory impairment, prolonged symptoms duration (≥36 h), elevated CRP (›5 mg/L), advanced ALI stage (Rutherford's class IIb), fasciotomy, and thrombosis etiology were associated with revascularization failure and amputation. To the best of our knowledge, this is the first report to investigate the ALI outcome and independent predictors of limb salvage following urgent open surgical revascularization in Yemen. Our report sheds light on the value of rapid revascularization in ALI patients and identifies those who will benefit the most from this revascularization strategy.

Table 3. Factors associated with amputation outcome.

Variables	Subgroups	No amputation (70)	Amputation (21)	*p*-value
Age (years)	Mean ± SD	55.0 ± 11.3	58.9 ± 12.0	0.179
Sex	Male	45 (64.3)	11 (52.4)	0.467
	Female	25 (35.7)	10 (47.6)	
Duration of symptoms	≤36 h	60 (85.7)	2 (9.5)	**<0.001**
	>36 h	10 (14.3)	19 (90.5)	
Ischemic heart disease	No	23 (32.9)	7 (33.3)	1.000
	Yes	47 (67.1)	14 (66.7)	
Hypertension	No	13 (18.6)	2 (9.5)	0.519
	Yes	57 (81.4)	19 (90.5)	
Diabetes	No	31 (44.3)	4 (19.0)	**0.037**
	Yes	39 (55.7)	17 (81.0)	
Hyperlipidemia	No	33 (47.1)	9 (42.9)	0.924
	Yes	37 (52.9)	12 (57.1)	
Cerebrovascular disease	No	63 (90.0)	17 (81.0)	0.463
	Yes	7 (10.0)	4 (19.0)	
Congestive heart failure	No	56 (80.0)	14 (66.7)	0.329
	Yes	14 (20.0)	7 (33.3)	
Hemodialysis	No	56 (80.0)	10 (47.6)	**0.008**
	Yes	14 (20.0)	11 (52.4)	
Artery involved	Superficial femoral artery	28 (40.0)	12 (57.1)	0.296
	External iliac artery	9 (12.9)	1 (4.8)	
	Popliteal artery	24 (34.3)	4 (19.0)	
	Brachial artery	9 (12.9)	4 (19.0)	
Extremity involved	Lower	61 (87.1)	17 (81.0)	0.722
	Upper	9 (12.9)	4 (19.0)	
ASA class	ASA I/II	16 (22.9)	3 (14.3)	0.656
	ASA III	44 (62.9)	14 (66.7)	
	ASA IV/V	10 (14.3)	4 (19.0)	
History of malignancy	No	68 (97.1)	15 (71.4)	**0.001**
	Yes	2 (2.9)	6 (28.6)	
ALI class	Rutherford I	7 (10.0)	1 (4.8)	**0.001**
	Rutherford IIb	49 (70.0)	12 (57.1)	
	Rutherford IIa	13 (18.6)	2 (9.5)	
	Rutherford III	1 (1.4)	6 (28.6)	
ALI cases	Thrombosis	60 (85.7)	13 (61.9)	**0.037**
	Arterial embolization	10 (14.3)	8 (38.1)	
Atrial fibrillation	No	38 (54.3)	6 (28.6)	**0.039**
	Yes	32 (45.7)	15 (71.4)	
Smoking	No	43 (61.4)	3 (14.3)	**<0.001**
	Yes	27 (38.6)	18 (85.7)	
Sensory impairment	No	60 (85.7)	1 (4.8)	**<0.001**
	Yes	10 (14.3)	20 (95.2)	
Low albumin	No	63 (90.0)	20 (95.2)	0.761
	Yes	7 (10.0)	1 (4.8)	
Anemia	No	61 (87.1)	15 (71.4)	0.172
	Yes	9 (12.9)	6 (28.6)	
Elevated CRP	No	64 (91.4)	12 (57.1)	**0.001**
	Yes	6 (8.6)	9 (42.9)	
Hospitalization	Mean (SD)	9.0 (3.1)	8.2 (3.5)	0.328
Fasciotomy	No	70 (100.0)	15 (71.4)	<0.001
	Yes	0 (0.0)	6 (28.6)	

Abbreviations: ASA, American Society of Anesthesiologists; ALI, acute limb ischemia; CRP, C-reactive protein.
Note: Bold indicates a statistically significant result ($P < 0.05$).

ALI can be treated surgically (thromboembolectomy and bypass surgery), endovascularly (catheter-directed thrombolysis, percutaneous thrombus aspiration, and stent implantation), or in a hybrid setting that includes both procedures.[9] A meta-analysis of five studies in 2013 compared surgical and endovascular treatment for ALI and found no significant difference in limb salvage or death rates between individuals, but endovascular therapies were associated with more severe sequelae, such as stroke and hemorrhage, within 30 days.[10] In this study, all ALI cases were treated with open surgical revascularization. This is primarily due to inadequate healthcare funding, a lack of skilled radiologic intervention, and a lack of endovascular tools for performing endovascular interventions.

To avoid occlusion and subsequent thrombosis development, immediate treatments with anticoagulants for all ALI-suspected individuals are recommended regardless of ALI reasons and even before diagnostic imaging, as the main objective is to remove the blood clot and restore blood flow as soon as possible.[11] Similarly, in this study, all ALI patients immediately received anticoagulant therapy before performing diagnostic imaging and laboratory investigations.

Many studies describe the amputation-free survival rates of ALI across different levels, different etiology, and different procedures, as well as functional results using varied period intervals. For example, Jungi et al. reported limb salvage after open surgical revascularization in ALI due to a thrombosed popliteal artery aneurysm in 51 patients. The 30-day mortality was 4% ($n = 2$). Four patients needed major amputation within 30 days, resulting in an overall major amputation rate of 16%.[12] In another study, Schrijver et al. compared the long-term outcomes of catheter-directed thrombolysis for acute lower extremity occlusions of native arteries versus prosthetic bypass grafts among 159 consecutive ALI patients. The 30-day mortality rate was 6% in native arteries and 1% in bypass grafts. The 30-day amputation rate was 10% in native arteries and 13% in bypass grafts. Amputation-free survival at 1 year was 76% for native arteries and 78% for bypass grafts and at 5 years was 65% for native arteries and 51% for bypass grafts.[13] Recently, Stoklasa et al. reported a large series including 985 ALI patients treated with endovascular therapy for 17 years (from 2004 to 2020). The 30-day and 180-day combined mortality and major amputation rates were 15% and 27%.[2] Additionally, a systematic review including 895 ALI cases by Kropman et al. reported that the mortality rate and amputation rate after the surgical repair were 3.2% and 14.1%, respectively.[14] Our result was in line with previous studies; in our study, 21 cases (23.1%) underwent amputation and one case expired postoperatively, given the amputation-free survival rate of 76.9% at a 1-month follow-up. Unfortunately, our result failed to report long-term outcomes result. As most patients were lost during follow-up. Therefore, the implementation of rigorously designed controlled prospective studies with longer follow-up time is pivotal to providing stronger evidence regarding amputation-free survival following vascular intervention in ALI patients.

Various factors have been reported as predictors of success and amputation following extremity revascularization. For example, Genovese et al. studied the risk factors for long-term mortality and amputation after open and endovascular treatment of ALI and discovered that the risk of mortality increased with age, female gender, malignancy, fasciotomy, in-situ thrombosis or embolic etiology, cardiac adverse events, respiratory failure, renal failure, and hemorrhagic events. Additionally, advanced ischemia (Rutherford IIb), thrombosed bypass etiology, open revascularization, and main intervention technical failure all enhanced the chance of amputation.[6] Advanced ischemia, a thrombosed bypass, and technical surgery failure were also reported as predictors of limb loss in several studies.[2,15,16] Another study looked at prognostic factors for long-term outcomes for amputation and death among ALI patients who received intra-arterial thrombolysis. The degree of lysis, motor deficit at admission, foot ulcers, and ischemic heart disease were identified as independent factors associated with amputation.[17]

Interestingly, Poursina et al. discovered that only age predicted mortality and/or amputation among ALI patients at the final follow-up.[18] While Andraska et al. reported worse short-term limb-related outcomes in young individuals with ALI caused by *de novo* thrombosis or embolus.[19] The independent predictors of limb loss in the Taylor et al. study were diabetes, impaired ambulatory status, end-stage renal disease, gangrene, and prior vascular intervention. Additionally, the probability of failure increased with the addition of each adverse predictor, with a worst-case scenario of 92.8%.[20] In another report by Londero et al., diabetes, stroke, coronary heart disease, and renal disease were associated with a higher risk of amputation without prior revascularization.[21] In this study, current smoking, history of diabetes, hemodialysis, history of malignancy, atrial fibrillation, sensory impairment, prolonged symptoms duration (≥36 h), elevated CRP (>5 mg/L),

advanced ALI stage (Rutherford's class IIb), and thrombosis etiology were associated with revascularization failure and postoperative amputation. Most of our findings were similar to previous reports with some variations. The observed variations could be attributable to disparate geographical populations and different patient comorbidities may contribute to the divergent factors influencing postsurgical outcomes. However, it is important to note that most of these studies were retrospective and monocentric. Consequently, there is a pressing need for prospective large-scale studies to provide a higher level of evidence.

In this study, the mean age of patients was 55.9 ± 11.5 years (range 35–79 years). It is worth noting that patient age was not an independent predictor of postoperative limb loss. A similar finding was mentioned by other studies.[18,20] Our finding highlights that advanced age should not be considered a contraindication to surgical revascularization in ALI patients.

In this study, most cases were males accounting for 61.5%. Our result is consistent with the previous report by Kazmi et al. who found the majority of ALI cases were male (65.6%).[11] However, other studies highlighted a higher illness grade, better limb salvage rates in open revascularization, and higher death among ALI females.[22]

In this study, prolonged symptom duration (>36 h) was associated with revascularization failure and amputation. Our result was similar to previous reports.[23,24] Limb salvage is crucially reliant on the length of ischemia, with a 10% drop in the likelihood of successful limb salvage for each hour of delay in revascularization.[11] However, there is evidence of effective limb salvage following vascular damage, even after 24 h of injury.[25]

The correlation between smoking and peripheral arterial disease is very strong and has been documented by a large number of studies. Smoking cessation reduces the risk of serious ongoing symptoms, amputation, and death due to vascular complications.[26,27] Additionally, the advanced ALI stage according to Rutherford's classifications was reported as a predictor for limb loss and amputations in several reports.[3,28] In Martelli et al.'s study, the only variables independently associated with loss of bypass patency were smoking and advanced ALI stage which was similar to our findings.[28] In this study, acute arterial occlusion led to immediately threatened limb ischemia (Rutherford IIb category) in 71.4% of cases. Other authors[29,30] provided similar results except for the study published by Sekar et al., where only 29% of cases were categorized as Rutherford IIb.[31] Additionally, in this study, eight patients were categorized as Rutherford I upon arrival with emboli etiology, and we opted to do immediate open revascularization, which was effective in all but one instance. As a result, in our vascular center, we first conducted surgical embolectomy for embolism. In Western nations, thrombolysis, particularly the use of recombinant tissue-type plasminogen activator (rt-PA), is one of the principal treatment options for a central thrombus, and varied results have been documented. However, because rt-PA is not permitted for all ALI in our country, we did a thrombectomy to shorten the occluded lesion while sparing the limb. A similar report was mentioned in Umetsu et al.'s study.[32]

In this study, hyperlipidemia was not associated with postoperative limb salvage. This finding is in contrast to a previous report that mentioned limb salvage was positively affected by a preoperative diagnosis of dyslipidemia that may be a proxy for statin use or a patient cohort with improved access to healthcare.[33] Additionally, other medical conditions such as ischemic heart disease and cerebrovascular disease were no statistically significant worse outcomes after ALI revascularization. Disparate geographical populations and different patient comorbidities may contribute to the divergent factors influencing postsurgical outcomes. Additionally, this may in part be due to smaller sample sizes as most studies that have looked at this have been limited to institutional data. Consequently, there is a pressing need for prospective large-scale studies to provide a higher level of evidence.

Baseline inflammatory status and cardiovascular event risk are linked to CRP values, which act as biomodulators of inflammation within arterial walls, promoting thrombosis. In our study, higher CRP values were observed among amputation cases. Our result was in line with previous reports.[34,35] CRP has been predictive of restenosis and cardiovascular events in other similar cohorts undergoing revascularization procedures.[36]

In this study, fasciotomy was performed in 6 (6.6%) patients and was substantially linked with the risk of amputation ($p < 0.001$). A similar finding was stated in previous articles by Rothenberg et al. and Natour et al.[37,38] This finding most likely reflects the severity of the initial injury. Additionally, a liberal approach to preventive fasciotomy during revascularization may enhance limb salvage rates.

In this study, the systemic complications occurred in 21 (23.1%) patients and were respiratory in 12 (13.2%), renal in 5 (5.5%), cardiovascular in 5 (5.5%), and rhabdomyolysis in 5 cases (5.5%). The local

complication was presented in 18 (19.8%) and SSI was the most common local complication (9.9%). In another study, Stoklasa et al. reported 985 ALI patients treated with endovascular therapy. The reported complications were cardiovascular events affected 13% of patients, respiratory failure 11%, and renal failure 9%, with rhabdomyolysis 5%. While the most common local complication was SSI (19%), other complications were hemorrhage (4%) and seroma/lymphatic fistula (6%).[2]

Study Limitations

The study results have several limitations, including a retrospective design that limits data collection, a small sample size that may limit statistical power, and insufficient data on family history, malignancy type, and stage or previous medical illnesses. These limitations make it difficult to draw sound conclusions and generalize the results to broader populations. Nonetheless, while big databases add important value due to greater power and sample size, a single institutional analysis may provide granular material that is not accessible in the broader research. Additionally, the outcomes assessed are limited to 30-day events. Wound complications generally occur within this period. However, they may develop beyond this time and would not be counted. To mitigate these limitations and provide more robust results, we recommend conducting a prospective study with a larger sample and longer follow-up.

CONCLUSION

In this study, despite no endovascular treatment offered, the application of the standard treatment—open surgical revascularization—in patients with ALI represents the key to success for limb salvage with acceptable amputation rates even in a resource-limited setting. Additionally, independent risk factors for amputation were current smoking, history of diabetes, hemodialysis, history of malignancy, atrial fibrillation, sensory impairment, prolonged symptoms duration (>36 h), elevated CRP (>5 mg/L), advanced ALI stage, fasciotomy, and thrombosis etiology. Advanced tailoring revascularization strategy and timing for the proper patient and comorbidities treatment could potentially improve amputation-free survival in ALI patients. Future studies should incorporate both limb severity and anatomic staging to best guide clinical decision-making in ALI.

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CONFLICT OF INTERESTS

The authors declared no conflict of interest.

AUTHOR CONTRIBUTIONS

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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