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Mid-term Outcomes of Image-Guided Surgical Thromboembolectomy and Routine Intraoperative Angiography for Native Vessel Acute Lower-Limb–Threatening Ischemia

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Abstract

Background: Standard balloon-catheter thromboembolectomy (TE) is an established effective treatment for acute lower-limb ischemia (ALI) with recognized limitations when there is an underlying arterial lesion or thromboembolism of the infrapopliteal arteries. The aim of this study was to evaluate the efficacy and safety of image-guided surgical TE combined with routine intraoperative completion angiography in the treatment of ALI patients.
Methods: Between September 2020 and August 2022, this prospective study included all consecutive adult patients presenting to a tertiary center with unilateral ALI of Rutherford class II due to thromboembolic occlusion of native arteries who underwent image-guided surgical TE and routine completion intraoperative angiography. Adjunctive endovascular techniques (hybrid revascularization) including plain balloon angioplasty (PTA)±stenting or on-table lysis were used if underlying arterial lesions or residual thrombosis were detected on the intraoperative angiography, respectively. The primary outcome measures included technical success and 30-day major amputation rate. Perioperative complications, 1-year primary and secondary patency, limb salvage, mortality, and amputation-free survival rates were endorsed as secondary outcome measures.
Results: Image-guided surgical thrombectomy was done for 109 ALI patients (109 limbs), provisionally diagnosed as embolic (57 patients, 52.3%) or thrombotic (52 patients, 47.7%) arterial occlusion. Thromboembolectomy without adjunctive endovascular treatment was done in 38 patients (34.86%), whereas 71 patients (65.14%) required adjunctive PTA±stenting of underlying arterial lesions (60, 55.05%) or on-table lysis±PTA of residual thrombosis (11, 10.09%). The overall technical success rate was 92.66%. At 30 days, amputation and mortality rates were 3.67% and 5.5%, respectively. None of the patients had thrombectomy-induced arterial injuries. One-year follow-up data were available for 81 patients (74.3%). The Kaplan-Meier estimate of the 12-month primary and secondary patency, limb salvage, and amputation-free survival rates was 76.5%±0.04, 91.5%±0.03, 90.6±0.03, and 91.4±0.03%, respectively.
Conclusions: Image-guided TE combined with routine intraoperative angiography is a safe and effective technique for surgical TE in acute lower-limb ischemia patients with the advantage of immediate identification and treatment of underlying arterial lesions or residual thrombosis for optimal revascularization.

Clinical Impact

The present study has confirmed the safety and effectiveness of image-guided thromboembolectomy combined with routine use of intraoperative angiography during surgical treatment of acute lower limb ischemia in terms of immediate identification and treatment of underlying arterial lesions or residual thrombosis for optimal revascularization. This technique also facilitates selective passage of Fogarty balloon catheter into infrapopliteal arteries from the femoral approach which is traditionally done by exploration of the popliteal trifurcation or tibial arteries under regional or general anesthesia. Using this technique can guide the operating surgeon for adequate balloon manipulation and inflation to avoid iatrogenic vessel injury.

Keywords

acute limb ischemia, image-guided thrombectomy, intraoperative angiography, endovascular therapy, arterial thromboembolism

Introduction

Regardless of the cause of acute lower-limb ischemia (ALI), whether an embolic or thrombotic occlusion of native artery, bypass graft, or stent, ALI represents a serious medical emergency with reportedly high postoperative amputation and mortality rates.[1] Therefore, it is of utmost importance to promptly diagnose and adequately treat ALI to prevent limb loss and other severe complications.

Both surgical and endovascular therapies are valid treatment options for ALI.[2] For decades, the relatively simple surgical thromboembolectomy (TE) with Fogarty balloon catheter has been the standard treatment for ALI with satisfactory results especially in cases of embolic ALI of larger non-diseased vessels.[3] The traditional blind surgical thrombectomy without fluoroscopic guidance, however, could lead to inadequate outcomes with concomitant peripheral arterial disease (PAD) or when infrapopliteal arteries are involved.[4] These pitfalls can be attributed to presence of untreated underlying arterial lesion or missing a residual thrombus especially when located in the smaller infrapopliteal arteries that are inaccessible to the embolectomy catheter.

Knowing those limitations of the standard surgical TE, it seemed practical to accept the concept of hybrid revascularization where surgical TE is performed under fluoroscopic guidance and concluded with routine intraoperative angiogram.[5,6] Utilization of this technique can also facilitate adjunctive endovascular treatment of arterial lesions or residual thrombi if detected on the intraoperative angiogram. However, the role of this technique for the surgical treatment of ALI has not been established yet, and many surgeons still reserve the use of intraoperative angiogram for cases with poor back-bleeding, inability to advance the embolectomy catheter to the distal leg, or after poor revascularization.[4,7]

Therefore, the aim of this study was to analyze the efficacy and safety of image-guided open surgical TE combined with routine intraoperative completion angiography and adjunctive endovascular treatment in ALI patients.

Materials and Methods

This study was prospectively conducted at a single tertiary center between September 2020 and August 2022. The study was conducted in accordance with the Declaration of Helsinki and was approved by the local Institutional Review Board (IRB No. 17101326). All study patients provided informed written consents before study participation.

Patients

The study included all consecutive adult patients presenting with unilateral ALI of Rutherford classes IIa and IIb[8] due to native thromboembolic occlusion who underwent image-guided thrombectomy and routine completion intraoperative angiography within 2 weeks of onset of symptoms. Acute lower-limb ischemia due to trauma or dissection medically unfit patients for intervention, and those presenting with Rutherford class I or irreversible acute limb ischemia (Rutherford class III) were excluded. Patients with blue toe syndrome, thrombosed aneurysm, contraindication to angiography (renal impairment with serum creatinine level >1.8 mg/dL or hypersensitivity to contrast agents), vasculitis, or any thrombophilia were also excluded.

Procedural Technique

Once diagnosis of ALI was confirmed by clinical examination, ankle brachial index (ABI) measurement, and duplex ultrasound (DUS) examination, a bolus of 5000 IU of unfractionated heparin sodium was given intravenously. Every effort was made to determine the cause of ALI whether embolic or thrombotic based on focused history taking and clinical and DUS examination. The very sudden onset of profound leg pain in a patient with cardiac dysrhythmia and normal pulses in the other limbs with no history, risk factors, clinical manifestations, or prior revascularization procedures for PAD were suggestive of embolic cause. On DUS examination, the appearance of a fresh embolus lodged at the bifurcations of normal appearing arteries indicated embolic ischemia in contrast to the chronically-diseased calcified arteries and appearance of collateral circulation that was associated with thrombosis.

To avoid any treatment delay and to minimize the incidence of contrast-induced nephropathy, additional imaging with computed topography angiography (CTA) was reserved to Rutherford class IIa patients with normal kidney functions if they had iliac artery occlusion or non-visualized distal runoff during DUS examination.

All surgical interventions were performed in a hybrid operating room equipped with C-arm (Philips BV Pulsera, Philips Medical Systems, Eindhoven, The Netherlands). Under close monitoring by an anesthesiologist, surgical procedures were performed under local infiltration anesthesia (2% lidocaine) or general anesthesia according to the patient's clinical condition.

A common femoral artery (CFA) approach was used to expose the common, superficial, and deep femoral arteries

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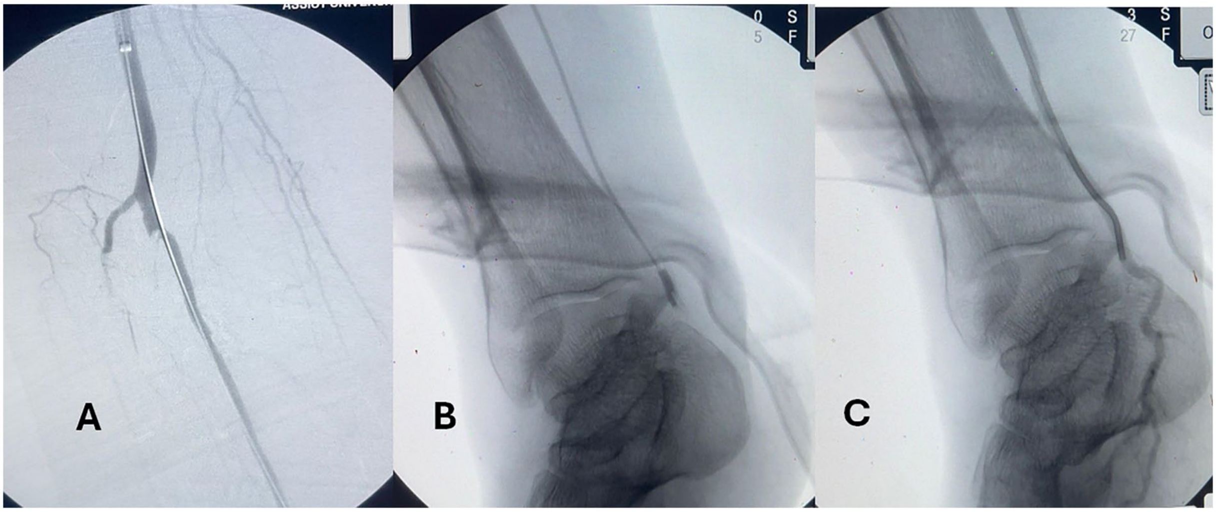

Figure 1. (A) Intraoperative angiography showing residual thrombus at the origin of the posterior tibial artery and a Fogarty catheter is selectively passed into the posterior tibial artery. (B) Image-guided thrombectomy showing indentation of the contrast-filled Fogarty catheter indicating the presence of underlying arterial lesion. (C) Intraoperative completion angiogram after balloon angioplasty of the underlying lesion showing complete thrombus removal with no residual stenosis or vessel injury.

via a longitudinal groin incision. Patients typically received 5000 IU of heparin sodium intravenously before cross-clamping of the artery. The CFA was opened via a transverse arteriotomy and surgical TE using contrast primed Fogarty embolectomy catheter (Edwards Lifesciences LLC, Irvine, California) was done under fluoroscopic guidance until no further clots were retrieved. In patients presenting with impalpable femoral pulse, a 6Fr, 11 cm-long introducer sheath (Prelude, Merit Medical Systems Inc, South Jordan, Utah) was introduced through the CFA arteriotomy in a retrograde fashion to perform intraoperative angiography to the iliac arteries.

In all patients, the introducer sheath was introduced into the CFA after closing the arteriotomy in an antegrade fashion to perform an intraoperative angiography to ensure complete clearance of the arterial supply to the foot. If the intraoperative angiogram showed steno-occlusive arterial lesion(s), plain balloon angioplasty (PTA) was performed. Selective bail-out stenting was done in case of residual stenosis >30% or flow-limiting dissections.

If residual thrombus was detected in the tibial-peroneal arteries on completion angiogram, the femoral arteriotomy was re-opened to pass the short sheath, and then a guidewire and directional catheter were used to access the target artery. The directional catheter and the short sheath were exchanged for a long 6F sheath, and the embolectomy catheter was passed through the long sheath into the target artery. Thromboembolectomy was continued under fluoroscopy by withdrawal of the contrast-filled Fogarty catheter along with the sheath (Figure 1). Residual thrombosis that could not be cleared with Fogarty catheter was treated with an attempt of intraoperative on-table thrombolysis using a 5 to 10 mg bolus dose of Alteplase (Actilyse, Boehringer-Ingelheim, Ingelheim am Rhein, Germany) via catheter infusion into the thrombosed arterial segment over 30 minutes.

In all patients, completion angiography was routinely performed to assess the technical success of the procedure and to verify the patency of the runoff arteries. If compartment syndrome was clinically suspected (eg, tense leg compartment combined with leg pain with passive motion, paresis, or paresthesia), fasciotomy was performed.

Clinical and Doppler assessment of foot perfusion was done before patients' transfer from the operating room. Detailed DUS examination was done on the first postoperative day. All patients were maintained postoperatively on low molecular weight heparin (enoxaprine, 1 mg/kg/12 h) for at least 5 days to be bridged for warfarin, targeting international normalized ratio (INR) value of 2 to 3. Patients who underwent balloon or stent angioplasty received additional aspirin (75 mg) for as long as 3 months.

Postoperative follow-up was done 1 month after discharge and every 3 months during the 1-year follow-up by clinical examination, ABI measurement, and DUS examinations to detect any arterial restenosis or occlusion. Indications of re-intervention during the follow-up were recurrence of ALI, or presentation with ischemic rest pain or ulcer.

Study Outcomes and Definitions

The primary outcome measures were technical success and 30-day major amputation rate. Perioperative complications, 1-year primary and secondary patency, limb salvage, mortality, and amputation-free survival were endorsed as secondary outcome measures.

Technical success was defined as restoration of in-line arterial flow of at least 1 artery to the foot or to the peroneal artery with good collateral flow to the pedal arteries using the described technique without any flow-limiting dissection or residual stenosis >30% on completion arteriography. Conversion to bypass surgery was considered a technical failure. Patency rates were calculated according to the published description.[8] Primary patency was defined as uninterrupted vessel patency with no revascularization procedures performed on the treated limb. Secondary patency was defined as an occluded artery that required intervention to restore patency. Limb salvage was defined as freedom from amputation proximal to the metatarsal bones. Complications were defined and categorized according to the criteria of the Society of Interventional Radiology.[9] Adverse events and deaths occurring within 30 days of the intervention were considered perioperative complications and mortality, respectively. Residual thrombosis was defined as detection of residual clots on intraoperative angiogram after no more clots were retrieved by repeated passages of Fogarty catheter during TE. Multilevel disease was defined as thromboembolism of the infrapopliteal arteries with concomitant proximal arterial involvement.

Statistical Analysis

Statistical analysis was performed using SPSS version 25.0 (IBM, Armonk, New York) and MedCalc version 16.8 (MedCalc Software, Ostend, Belgium). Continuous variables were expressed as mean±standard deviation (SD) and/or median and interquartile range (IQR). Categorical variables were reported as frequency and percentage. One-year patency, mortality, limb salvage, and amputation-free survival rates were analyzed by intention-to-treat analysis using Kaplan-Meier survival curves and were reported as proportion±standard error.

Results

Baseline Characteristics and Immediate Outcomes

Out of 284 patients presenting with non-traumatic ALI during the study period, the study included 109 patients (109 limbs) presenting with unilateral thromboembolic ALI of native arteries who underwent image-guided open surgical TE and routine intraoperative completion angiography. Numbers of the excluded patients stratified according to the cause of exclusion are illustrated in Figure 2 and were excluded from further analysis. The mean age of the study patients was 65±10 years who were mostly males (78%), smokers (69%), and diabetic (68%). Upon presentation, patients were categorized as Rutherford class IIa (40, 36.7%) or class IIb (69, 63.3%) ALI. Based on the preoperative clinical and DUS examination, the provisional cause of ALI was embolic in 57 patients (52.29%) and thrombotic in 52 patients (47.71%) and the site of thromboembolism was mainly at the femoropopliteal arterial segment (45, 41.3%). Patients' demographic data, comorbidities, and clinical presentation criteria are presented in Table 1.

Table 2 shows the procedural details of the study patients. Most revascularization procedures (82%) were done under local anesthesia, whereas 18% of the patients were operated under general anesthesia. Of the 109 procedures, TE without adjunctive endovascular therapy was done in 38 patients (34.86%) resulting in restoration of blood flow to the foot without residual arterial lesions in 36 patients (36/38, 94.74%) as shown on the intraoperative angiogram. Thromboembolectomy failed in the remaining 2 patients who required bypass surgery that was successful in 1 patient but failed in the other patient resulting in a subsequent major amputation.

For the remaining 71 patients (65.14%), intraoperative angiography after TE indicated the need for adjunctive endovascular techniques (hybrid revascularization) to restore satisfactory vessel patency. Hybrid procedures included PTA±stenting of underlying arterial lesions (60 patients including 8 stents) or on-table lysis±PTA (11 patients) of residual thrombosis that could not be cleared with TE. Plain balloon angioplasty±stenting was done for 19 iliac, 33 femoropopliteal, 2 infrapopliteal, and 6 multilevel arterial lesions. Of the 71 hybrid revascularization procedures, 65 procedures (65/71, 91.55%) were technically successful resulting in an overall technical success rate of 92.66% (101/109). Technical failures in the hybrid group occurred in 6 patients (6/71, 8.45%) including 2 patients with failed iliac PTA±stenting who were treated with femoro-femoral bypass surgery that was successful in 1 patient whereas the other patient had major amputation after graft thrombosis and failed attempt of graft thrombectomy. Lysis treatment failed in 4 patients who underwent bypass surgeries that were successful in 2 patients whereas the remaining 2 patients underwent major amputation. The operative diagnosis of the cause of ischemia was embolism in 43 patients (39.45%) or thrombosis in 66 patients (60.55%). The overall 30-day amputation rate was 3.67% (4/109), including 1 amputation from embolic ALI patients (1/43, 2.33%) and 3 amputations from thrombotic ALI patients (3/66, 4.55%). Perioperative amputations were

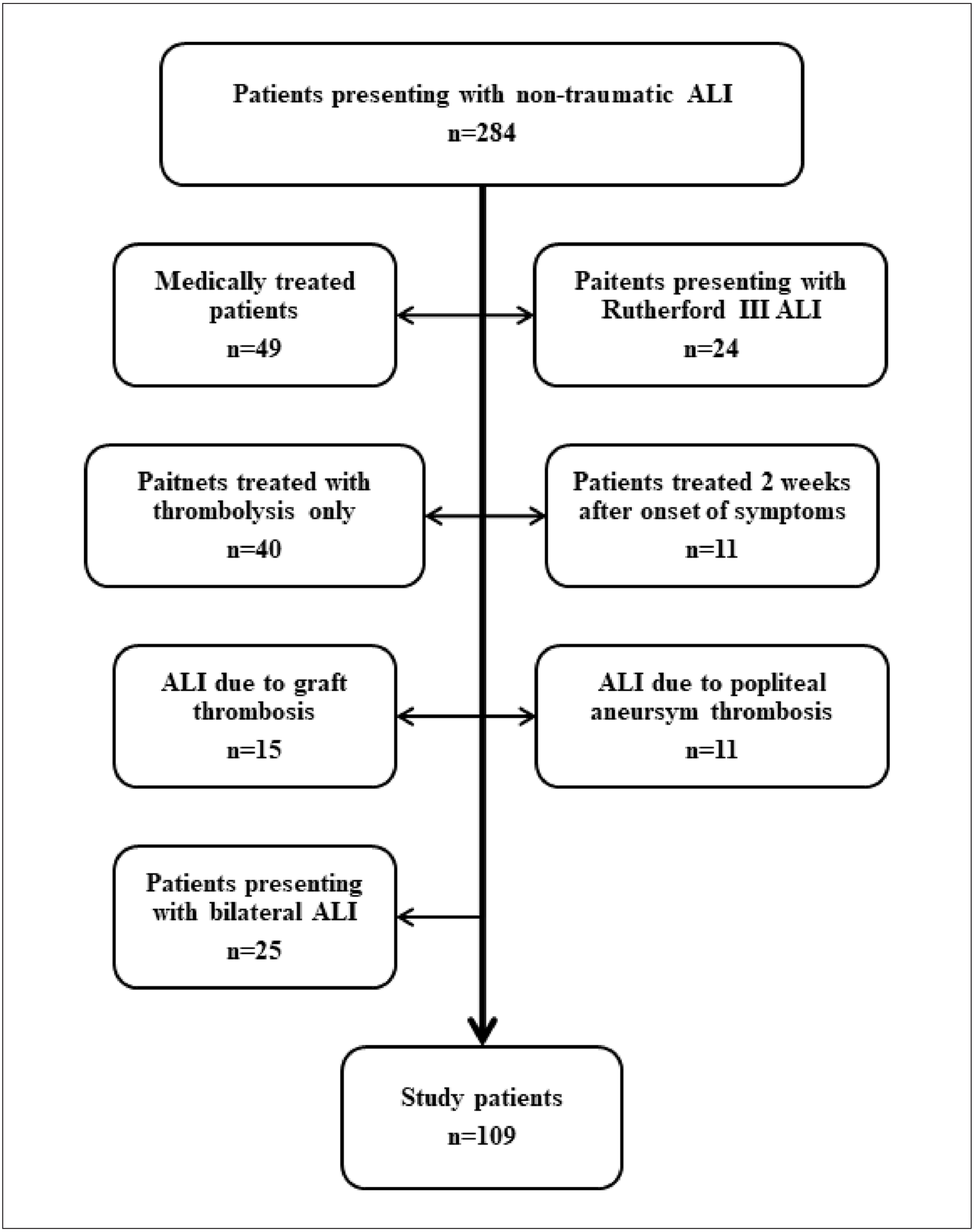

Figure 2. Flowchart representing numbers of the excluded patients stratified by the cause of exclusion. ALI, acute lower-limb ischemia.

Table 1. Demographics, Comorbidities, and Clinical Presentation of the Study Patients.

	N	%
Age, years		
Mean±SD	65±10	
Median (IQR)	65 (40-88)	
Male gender	85	77.98
Smoking	75	68.81
Diabetes mellitus	74	67.89
Hypertension	53	48.62
Dyslipidemia	51	46.79
Coronary artery disease	38	34.86
Atrial fibrillation	43	39.45
Previous ipsilateral revascularization	32	29.36
History of stroke	19	17.43
CKD (S. creatinine 1.2-1.8 mg/dL)	11	10.09
Affected lower limb		
Left	65	59.63
Right	44	40.37
Duration of symptoms		
<6 h	26	23.85
6-24 h	50	45.87
>24 h	33	30.28
Rutherford severity class		
Class IIa	40	36.70
Class IIb	69	63.30
Location of thromboembolism		
Iliac	26	23.85
Femoropopliteal	45	41.28
Infrapopliteal	14	12.84
Multilevel	24	22.02
Provisional cause of ischemia		
Embolic	57	52.29
Thrombotic	52	47.71

Continuous data are presented as the means±standard deviation (SD) and/or median and interquartile range (IQR); categorical data are given as the counts (percentage).
Abbreviation: CKD, chronic kidney disease.

Table 2. Procedural Details.

	N	%
Type of anesthesia		
General	20	18.00
Local	89	82.00
Operative diagnosis of ischemia		
Embolic	43	39.45
Thrombotic	66	60.55
Revascularization procedure		
TE without selective arterial cannulation	21	19.27
TE with selective arterial cannulation	17	15.60
Hybrid revascularization	71	65.14
TE+PTA	52	47.71
TE+PTA+stenting	8	7.34
TE+on-table lysis	7	6.42
TE+on-table lysis+PTA	4	3.67
Site of underlying lesion/residual thrombosis		
Iliac	19	17.43
Femoropopliteal	33	30.28
Infrapopliteal	13	11.93
Multilevel	23	21.10
Arteriotomy closure		
Primary closure	95	87.16
TEA+patch angioplasty	14	12.84
Patch type		
Vein patch	11	
Prosthetic patch	3	
Fasciotomy	11	
Procedural time, min		
Mean±SD	71.2±23.56	
Median (IQR)	65 (63-67.5)	

Continuous data are presented as the means±standard deviation (SD) and/or median and interquartile range (IQR); categorical data are given as the counts (percentage).
Abbreviations: PTA, plain balloon angioplasty; TE, thromboembolectomy; TEA, thromboembolectomy.

Table 3. Perioperative Complications.

	N	%
Arterial perforation	9	8.26
Recurrent thrombosis	2	1.83
Superficial wound infection	4	3.67
Lymphorrhea	4	3.67
Acute myocardial infarction	2	1.83
Metabolic acidosis	3	2.75
Cerebrovascular stroke	1	0.92
Reversible acute renal failure	2	1.83
Major amputation	4	3.67
Multiorgan failure	1	0.92
Unplanned return to the OR	15	13.76
Death	6	5.50

Abbreviation: OR, odds ratio.

observed in 1 patient of Rutherford class IIa ischemia (1/40, 2.5%) and 3 patients from class IIb (3/69, 4.35%).

Perioperative mortality occurred in 6 (5.5%) patients due to extensive reperfusion injury and metabolic acidosis (n=3), acute myocardial infarction (n=1), extensive cerebrovascular stroke (n=1), and multiorgan failure (n=1). Specifically, 3 deaths occurred in embolic ALI patients (3/43, 6.98%) and 3 deaths in thrombotic ALI patients (3/66, 4.55%). Perioperative mortality was evenly split between Rutherford class IIa (3/40, 7.5%) and IIb patients (3/69, 4.35%). One patient sustained postoperative acute myocardial infarction that was successfully treated with primary coronary stenting. Other perioperative complications (Table 3) included 2 patients with recurrent thrombosis of the treated limb who were successfully treated with redo

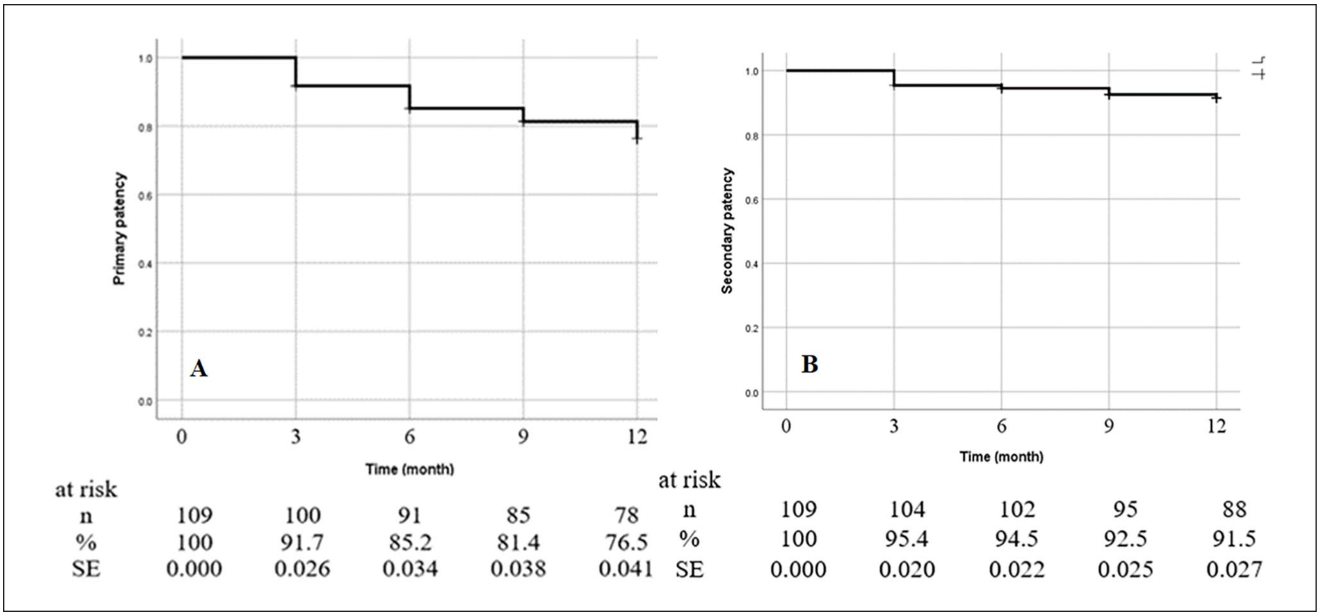

Figure 3. Kaplan-Meier curve of the 12-month primary (A) and secondary (B) patency rates of the study patients.

image-guided surgical thrombectomy. Two patients had postoperative reversible acute kidney injury. Nine patients had minute vessel perforations caused by the guidewire and were treated with prolonged PTA. There were no thrombectomy-induced arterial injuries.

Mid-term Outcomes

Mean duration of follow-up was 12±2.93 months and the median was 12 months (IQR=11.5-12 months). The 12-month follow-up data were available for 85 patients (78%). Fourteen patients (12.84%) were lost to follow up. In addition to the 6 perioperative deaths, 4 patients died during the follow-up (3 patients with embolic ALI and 1 patient with thrombotic ALI) due to cardiac events (n=2) or cerebrovascular stroke (n=2). The overall 12-month mortality was noted in 4 and 6 patients of Rutherford class IIa and IIb, respectively. The Kaplan-Meier estimate of 1-year mortality rate was 12.9%.

During the follow-up, 22 patients experienced recurrent limb ischemia, including 5 patients (2 from the embolic and 3 from the thrombotic ALI groups) were diagnosed with irreversible ALI and underwent primary major amputations. Those 5 patients were categorized at enrollment as Rutherford class IIa (n=2) or class IIb (n=3) ALI. The remaining 17 patients were successfully treated with PTA (10 patients) or PTA and stenting (7 patients). The Kaplan-Meier estimate of the 12-month primary and secondary patency (Figure 3), amputation-free survival (Figure 4), and limb salvage rates were 76.5%±0.04, 91.5%±0.03, 91.4%±0.03, and 90.6%±0.03 respectively.

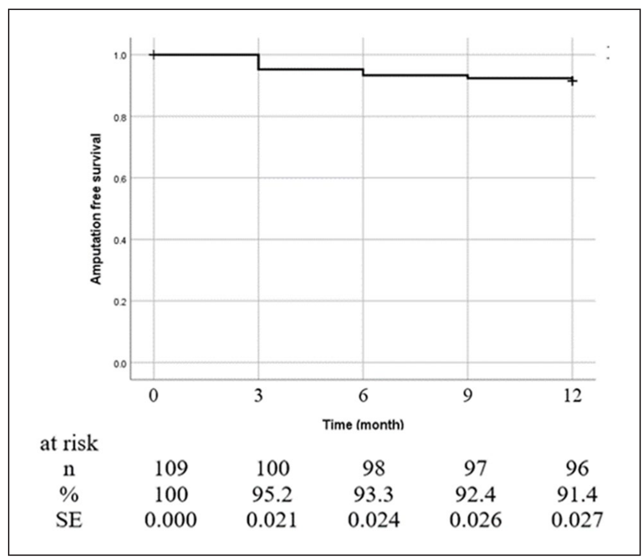

Figure 4. Kaplan-Meier curve of the 12-month amputation-free survival rate of the study patients.

Discussion

Acute lower-limb ischemia is one of the most common vascular emergencies that is associated with high risk of morbidity and mortality. For decades, traditional surgical embolectomy, being an effective, relatively simple, and quick procedure, has remained the treatment of choice for embolic ALI in otherwise healthy arteries. Although arterial embolism is still a common cause of ALI, the rate of associated underlying arterial lesions is rising due to increased proportions of elderly patients with multiple comorbidities including atherosclerosis.[1,10] The population-based Oxford Vascular Study[11] stated that 42% of ALI patients had a pre-existing PAD and 40% had known risk factors of atherosclerosis, with increasing prevalence rates over time.[1]

In the present study on ALI patients due to thromboembolic native vessel occlusion, most of the study patients had known risk factors for atherosclerosis, including smoking (69%), diabetes (68%), hypertension (49%), dyslipidemia (47%), coronary artery disease (35%), stroke (17%), and previous ipsilateral revascularization (29%). Although 52% of our patients were provisionally diagnosed as embolic ALI, intraoperative angiograms showed underlying arterial lesions in 66 patients (60.6%). These high rates of risk factors for vascular disease among ALI patients exemplify the rarity of finding pure embolic occlusion in modern surgical practice.

On the contrary, detection of residual thrombosis after TE has been found to occur in up to 30% of cases as shown by completion angiograms[10,12] and in up to 83% by video angioscopy.[13] In this study, residual thrombosis was found in 28 patients (25.69%), which could have been missed if routine intraoperative angiogram was not pursued. Thus, completion angiography after surgical TE has been recommended by the European Society for Vascular Surgery (ESVS) to identify and treat residual arterial lesions or missed thrombus.[2]

The preoperative differentiation between embolic and thrombotic ischemia can be difficult or even clinically impossible in 10% to 15% of cases.[14] In a study by Kauhanen et al,[15] preoperative diagnosis of the cause of ALI was incorrect in 30% of embolic and 54% of thrombotic ALI cases when compared with the definitive operative diagnosis. These pitfalls in the preoperative clinical diagnosis of ALI etiology led the authors of that study to highlight the importance of using routine intraoperative angiography for adequate evaluation and treatment.

The advantages of routine intraoperative completion angiography after surgical TE have been previously reported including identification and treatment of concurrent atherosclerotic lesions, residual thrombosis, or even iatrogenic vessel injury caused by the TE itself.[5,6,16] In this study, the use of intraoperative completion angiogram after TE showed concomitant arterial lesions or residual thrombosis demanding adjunctive endovascular procedures in 65% of the patients. In a similar study on hybrid revascularization of ALI patients, intraoperative completion angiograms after surgical TE showed imperfect revascularization requiring further treatment in 86% of their patients.[4] In another study on 21 patients with acute arterial or bypass graft occlusion, intraoperative completion angiogram after TE showed 15 (71.4%) residual lesions that were successfully treated with repeat thrombectomy (n=8), PTA (n=3), and stenting (n=4).[5]

Intraoperative angiography can be particularly useful in those patients who could not have a preoperative CTA. Digital subtraction angiography (DSA) is still considered the gold standard for diagnosing ALI that can amend the limitations of DUS in the acute setting including its lower diagnostic accuracy with heavy calcifications, tibial lesions, and with multilevel disease.[17] Therefore, CTA was recommended by the ESVS guidelines as the first line modality for anatomical imaging despite the association between the use of iodinated contrast and acute kidney injury.[2] This may explain the discrepancy observed in the incidence of embolic and thrombotic ALI in this study between the provisional preoperative diagnosis (based on the clinical and DUS examinations) and the definitive operative diagnosis attained by intraoperative DSA.

It has been argued that utilization of routine completion angiography after TE might not be justified as procedural success can be simply assessed by foot inspection, ABI measurement, and DUS examination.[18] In a study by Zaraca et al,[7] comparing routine vs selective intraoperative angiography during TE for ALI, the indications for selective angiography were the ischemic appearance of the foot after TE, poor back-bleeding, or failure to introduce the Fogarty catheter to the distal leg. With these strict clinical indications for selective angiography based on the least suspicion of incomplete revascularization, routine angiography in their study still showed a higher need for adjunctive treatment in patients receiving thrombectomy (53.4% vs 29.9%, p=0.003) or embolectomy (17% vs 9.2%, p=0.08), although the latter did not reach statistical significance. Although the amputation rates were comparable between the routine and selective angiography groups, the re-occlusion rates at 24 months were significantly lower in the routine angiography group in both thrombectomy and embolectomy patients. This may suggest that identifying and amendment of suboptimal revascularization, that could have been overlooked by the clinical judgment, may also affect the long-term outcomes if left untreated. The long-term impacts of compromised distal runoff after endovascular treatment of superficial femoral artery have been clearly demonstrated in chronic limb ischemia patients in terms of worsened patency, symptom recurrence, and limb salvage as compared to the treated patients with good runoff and despite the comparable and satisfactory technical success among the studied groups.[19] Although acute limb ischemia and chronic limb ischemia are completely different entities, this may signify the importance of identifying and treating any residual arterial lesions or thrombosis for improved both immediate and late outcomes. Using routine intraoperative angiography may have contributed to our satisfactory technical success rate (92.7%), primary patency (76.5%), and limb salvage (90.6%) rates at 1 year. Our rates are comparable to the corresponding rates reported by another study using the same technique (90.4%, 86.1%, and 88.5%, respectively).[20]

In this study, thromboembolism of the leg vessels occurred in 33% of the patients. In those patients, the traditional blind TE can be quite challenging as the operating surgeon cannot pass the Fogarty catheter from the femoral approach into a particular leg artery. Consequently, exploring the distal popliteal and/or the tibial-peroneal arteries may be needed to selectively introduce the Fogarty catheter into a particular vessel for complete thrombus removal. One important advantage of image-guided thrombectomy is obviating the need for distal arteriotomy.[21] Using this technique, exploration of popliteal trifurcation or leg vessels for TE was not needed in this study. Decreasing the magnitude of the revascularization procedure and avoiding distal incisions that mandates regional or general anesthesia are particularly useful in the setting of ALI with impaired patients' general status and lacking the time to optimize their medical conditions. In this study, most procedures (82%) were done under local anesthesia, while reserving general anesthesia (18%) for uncooperative, anxious, or neurologically-impaired patients.

Another advantage of image-guided thrombectomy is the accurate control of Fogarty balloon inflation to avoid overdistension and possible damage of both normal and diseased arterial segments. This was done by observing the balloon shape for deformities, indentation, tapering, or over inflation while feeling the resistance to catheter retraction.[6] None of the study patients were complicated with thrombectomy-induced arterial injury, dissection, pseudoaneurysms, or arteriovenous fistulae. However, minute arterial perforations caused by the guidewire occurred in 9 patients and were immediately treated with prolonged balloon angioplasty. In a study by De Donato et al,[4] 8 patients (2.5%) were complicated with iatrogenic arterial injuries secondary to Fogarty catheter embolectomy (5 dissections, 1 perforation, 1 post-traumatic aneurysm) which required endovascular repair.

Admittedly, there are several limitations in this study including lack of homogeneity regarding the cause of ALI or the used endovascular technique in the treated patients who did not allow for direct comparisons of outcomes in the different patients' subgroups. Also, lacking the patency and re-intervention rates beyond the first year precluded assessment of the long-term benefits of the routine use of image-guided thrombectomy and completion angiography in ALI patients.

Conclusions

From the results of this study, we can conclude that for patients presenting with ALI, image-guided TE combined with routine intraoperative angiography is a safe and effective technique for TE with the advantage of immediate identification of imperfect surgical revascularization. It can also facilitate simultaneous endovascular treatment of the underlying arterial lesions or residual thrombosis for optimal revascularization. Large-scale multicenter studies with long-term results are still needed to enable objective comparison of outcomes after selective versus routine use of this technique.

Prior Presentation

This study has not been previously presented in any scientific meeting.

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Declaration of Conflicting Interests

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