Endovascular tibial arteries revascularization and its outcome on wound healing with split-thickness skin grafts for limb salvage in patients with below-the-knee vascular disease

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Background
Continuous and rapid advancement in percutaneous endovascular therapy has led to a significant increase in its use as a primary option for revascularization replacing surgical bypass, and it has become a standard treatment for critical limb ischemia (CLI). Clinical success of percutaneous revascularization has been mostly judged by patency rate and limb salvage, but there is paucity of reports on the outcomes of the wound. We present a retrospective study of immediate angiographic and 6-month clinical outcome of patients who underwent endovascular recanalization of tibial arteries for CLI followed by surgical debridement and wound reconstruction with split-thickness skin graft (STSG) for patients with grade 2 ulcer according to the Wound, Ischemia, foot Infection score.

Patients and methods
Between January 2016 and April 2017, 47 consecutive adult patients with CLI who underwent endovascular recanalization of infra-popliteal arteries due to more than 50% stenosis or chronic total occlusion with grade 2 chronic wound that was reconstructed using STSG and who had a clinical follow-up of at least 6 months were selected for analysis.

Results
Forty-seven patients underwent endovascular reconstruction. Forty (85.1%) patients underwent only balloon angioplasty and remaining seven (14.9%) underwent additional bailout stenting for proximal tibioperoneal or anterior tibial arteries. Twenty-eight (59.6%) patients had multiple vessel recanalization, while 19 (40.4%) patients had single vessel recanalization. Linear flow to the foot was achieved in at least one artery, mostly the anterior tibial artery in 32 (68.1%) patients postrevascularization. Successful wound healing occurred in 37 (80.4%) patients, 24 (64.9%) of them underwent wound covering with STSG with graft uptake in 20 (83.3%) patients. Limb salvage was achieved in 41 (89.1%) patients at a 6-month follow-up.

Conclusion
Endovascular recanalization of tibial arteries is an effective procedure for the treatment of CLI. STSG can be considered a reliable option for achieving wound healing in diabetic foot patients after successful revascularization and proper wound debridement. Normal outflow with at least one of the three infra-popliteal vessels being patent is essential for adequate healing and graft taking.

Keywords:
critical limb ischemia, split-thickness skin graft, endovascular recanalization

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Introduction

Critical limb ischemia (CLI) is an advanced form of peripheral arterial disease in which the tissue viability is threatened due to crural decrease in arterial blood flow to the foot resulting in rest pain, nonhealing foot ulcers, tissue necrosis, and gangrene [1]. In those patients, surgical revascularization should be adopted as the treatment option in patients having suitable anatomical conditions; however, due to involvement of the pedal arteries by the atherosclerosis or high surgical risk in most of the patients, surgical bypass is not always feasible [2]. Endovascular treatment options are gaining acceptance as the primary therapeutic strategy with the development of new technologies, such as dedicated guidewire or low-profile catheter balloons [3]. In fact, since its initial applications, endovascular recanalization of tibial vessels and foot arteries has proven to be feasible and safe procedures that have revolutionized salvage of the ischemic limb [4]. The use of split-thickness skin graft (STSG) is effective in the management of the wound healing process regardless of the location of wound and presence of diabetes, so it is considered a viable option in the care of dorsal and plantar diabetic foot wounds [5]. As patients with CLI had multiple underlying pathologies like impairment of tissue perfusion in association with tissue necrosis and loss in the form of gangrene and ulcer, correction of tissue perfusion solely in many patients was not enough to achieve limb salvage. We established a surgical team to deal with the multifactorial process of CLI representing the cooperation between the vascular and the plastic surgeons to accelerate healing of large foot wounds after successful revascularization. We also addressed the effect of this multidisciplinary approach on the rate of wound healing and limb salvage.

Patients and methods

Our study was conducted as a 'retrospective observational study' that included an analysis of 47 consecutive patients with CLI of different age and sex who were scheduled for below-knee angioplasty between January 2016 and April 2017 due to more than 50% stenosis or chronic total occlusion with grade 2 chronic wound according to the Wound, Ischemia, foot Infection score that was reconstructed using STSG with a clinical follow-up of at least 6 months from the last patient operated upon. It was performed at two hospitals, Benha University Hospitals and Nile Insurance Hospital after our institutional review board approved the protocol. Age eligible for our study is 40 years and older. Both sexes were eligible for the study.

Inclusion criteria

The patient must meet all of the following inclusion criteria:

(1) Patients with CLI due to de novo isolated infrapopliteal atherosclerotic disease and Rutherford categories 5 (minor tissue loss) and 6 (major tissue loss).
(2) Patients from 40 to 75 years old.
(3) Diabetic patients type I and type II.
(4) Patient must agree to undergo the 6-month duplex follow-up as well as the clinical follow-up (at 6 months postprocedure).
(5) Lesion criteria included de novo tibial arteries stenotic lesions of at least 50% or total occlusion of the tibioperoneal trunk and its branches.

The lesions were diagnosed by computed tomography angiography or conventional arteriography.

Exclusion criteria

The patient must not meet any of the general exclusion criteria:

(1) Previous surgery in the target vessel.
(2) Acute myocardial infarction within 30 days before intervention.
(3) Acute thrombus or aneurysm in the index limb or target vessel (presence of stent in the target lesion).
(4) Arteritic and inflammatory disease.
(5) Renal insufficiency with a serum creatinine of more than 2.0 mg/dl at baseline biochemical testing.
(6) Platelet count of less than 50 000/ml or more than 600 000 at baseline hematological testing.
(7) Known or documented thrombophilia necessitating long-term anticoagulant therapy.
(8) Known or documented hypersensitivity or contraindication to contrast agent that cannot be adequately premedicated.
(9) Patient with intolerance of antiplatelet or thrombolytic medications that would be administered throughout the trial enrolment.

Procedure and medical therapy

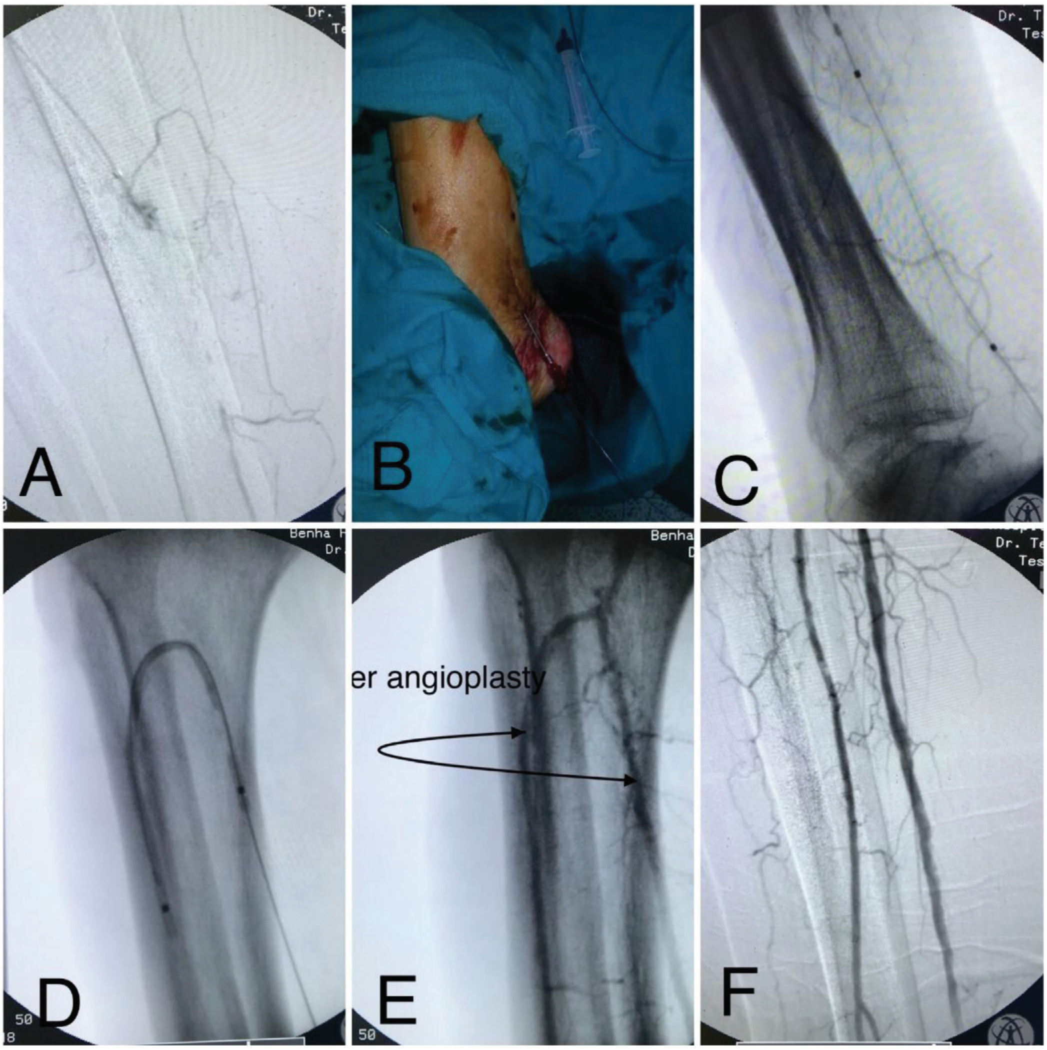
Initial broad-spectrum antibiotics in addition to preoperative and postoperative debridement and minor amputations (toe/s or transmetatarsal without affecting the pedal arch) for patients presenting with wet gangrene/necrotic tissue or sloughs in the wound bed. Periprocedural medications used were clopidogrel loading dose (300 mg) and oral acetyl-cysteine 600 mg once with good hydration at a rate of 0.5 ml/kg/h normal saline for 6 h before and after the procedure. In patients receiving metformin treatment, even those who had a glomerular filtration rate greater than or equal to 60 ml/min/1.73 m^2, metformin treatment was stopped 48 h prior to the intervention and started 48 h after the procedure provided the renal function was normal. Endovascular procedures were performed under local infiltration anesthesia (xylocaine 2%: 3–5 mg/kg), percutaneously by antegrade through 6 F sheath or through contralateral/crossover approach through 8 F sheath. Unfractionated heparin was recommended during the endovascular procedure (80–100 IU/kg). Selective diagnostic angiography of the tibial vessels by injecting the dye at the level of popliteal artery through a vertebral or multipurpose catheter (Fig. 1a). Based on the baseline angiography we determined tibial target lesions according to (a) lumen compromise, (b) lesion length, and (c) distal reconstitution. We attempted recanalization of at

Figure 1

Chronic total occlusion (CTO) of leg course of ATA and PTA: (a) balloon angioplasty of ATA and PTA by pedal-plantar loop technique; (b, c, and d) no residual postangioplasty dissection or stenosis in tibial and foot arteries (e and f). PTA, percutaneous transluminal angioplasty.

least one tibial artery; our choice of the target artery was based on the site of tissue loss; however, sometimes preference was given to those arteries exhibiting angiographically verified pedal reconstitution (Fig. 1b and c). Crossing and dilatation were performed using mainly low-profile equipment (0.018′ or 0.014′). Cannulation of the targeted vessel using a road map under fluoroscopic guidance with a 0.018’ (V-18 by Boston Scientific, Natick, Massachusetts, USA or Nitrex by ev3; AqWire, Plymouth, Minnesota, USA) guidewire. In some cases, the guidewire was 0.035′ hydrophilic type (ev3) (ZIP Wire; Boston Scientific). We directed the wire into the targeted vessel by a vertebral catheter. Balloon dilatation of the tibial vessels was performed with a 3 mm balloon (Sterling SL Monorail posterior tibial artery (PTA) Balloon Directed Catheter by Boston Scientific) and (Amphirion by Medtronic, Santa Rosa, CA, USA) over a 0.018 guidewire. In some cases, we used an additional retrograde sheathless pedal access due to failed antegrade crossing the lesion due to vessel perforation or calcified cap (Fig. 2a and b). Bailout stenting using drug-eluting stents (Xience Xpedition by Abbott vascular, Santa Clara, CA, USA) was deployed in residual stenosis of more than 30% or dissection not sealed by balloon inflation mainly in patients with a recanalized single runoff vessel to secure optimum inline flow to the pedal arteries (Fig. 3e and f). The last step is completion angiography to confirm successful angioplasty (Figs 1–3). Technical success was defined as attainment of less than 30% residual stenosis of the treatment area. Postoperative medical therapy included aspirin

Figure 2



PTA perforation during antegrade wire navigation (a), PTA retrograde sheathless access (b), successful crossing the lesion and perforation with balloon inflation to seal the injury (c), retrograde over the bifurcation balloon angioplasty (d), completion angiogram and satisfactory results (e, f). PTA, percutaneous transluminal angioplasty.

(minimum 81 mg/day for a minimum of 6 months) and clopidogrel daily for a minimum of 1 month for nonstented patients and 3 months for patients who received stents.

Postprocedural

The wounds were photographed preoperatively and postdebridement and were followed up with photographs at 2 weeks, and at 1, 2, and 4 months. All wounds were classified as either granulating with ongoing healing progress, complicating in the form of infection or gangrene or getting lost at the time of each review. All dressings were performed depending on the wound status. Dressings and wound evaluation were performed daily, initially after the arterial intervention, and later at alternate day/every third day, once adequate granulation tissue was noted to cover the wound and wound epithelialization had started. Further intermittent debridement was performed as dictated by the wound status either as an outpatient procedure or in the operating room. Foot counseling and appropriate offloading footwear were advised to all patients to help early ambulation. STSG was performed over granulating wound with large surface area as an alternative way for achieving rapid wound healing (Figs 4–6).

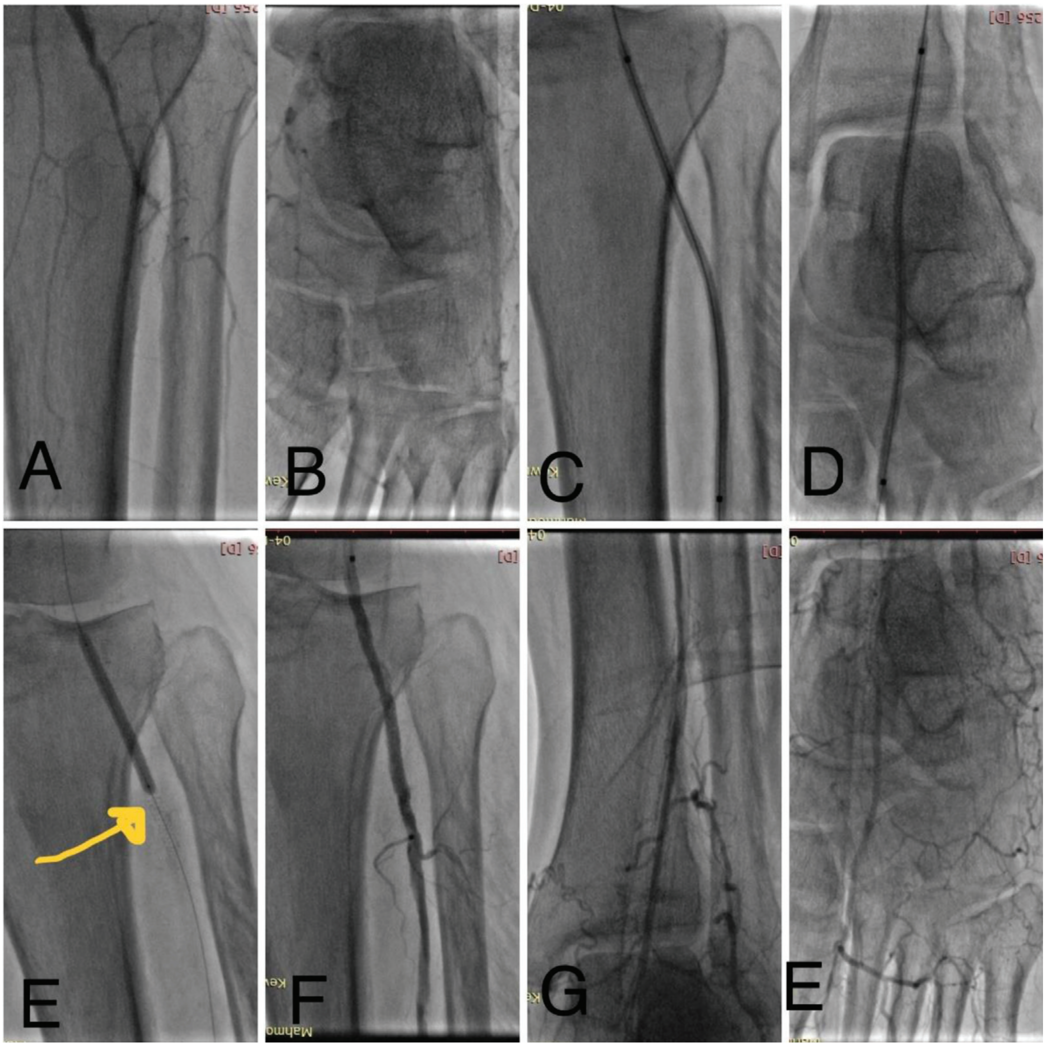
Follow-up

The enrolled patients were clinically evaluated before discharge, at 1, 3, and 6 months after the procedure, and their Rutherford classification was reassessed. The patency of the treated arterial segment was assessed by duplex ultrasonography for the superficial femoral artery (SFA), proximal popliteal, and tibial arteries.

Study endpoints

We considered our procedures were successful when we were able to restore straight-line flow down to the foot circle in at least one crural artery with no significant

Figure 3



Chronic total occlusion (CTO) of tibioperoneal trunk and ATA: (a) desert foot, (b) balloon dilatation of ATA and DP, (c, d) stenting of proximal ATA due to high calcified lesion yellow arrow, (e) adequate inline-flow to planter arch (e–g).

residual stenosis (>30%). When the peroneal artery was the only revascularized artery, we considered success in case of good distal collaterals to the foot circle. The primary endpoints of the study were achievement of wound healing and limb salvage and freedom from major amputation during the enrolled period. The secondary endpoints were primary patency was defined as the absence of TLR and binary restenosis assessed by DUS or angiography if DUS was uninformative, and the clinically driven target lesion revascularization (cdTLR) rate at 6 months. A reintervention was allowed in case of at least 70% diameter stenosis (confirmed by duplex ultrasonography, computed tomography, or conventional angiography) with documentation of failure to heal due to restenosis.

Statistical analysis

Data management and statistical analysis were done using SPSS version 25 (SPSS Inc., Chicago, IL, USA). Numerical data was summarized as mean and SD. Categorical data was summarized as numbers and percentages. Healing process at different follow-up points were compared using Cochran's Q test. P value was two sided and significance threshold was adjusted to 0.05.

Results

Patient, lesion, and procedural characteristics

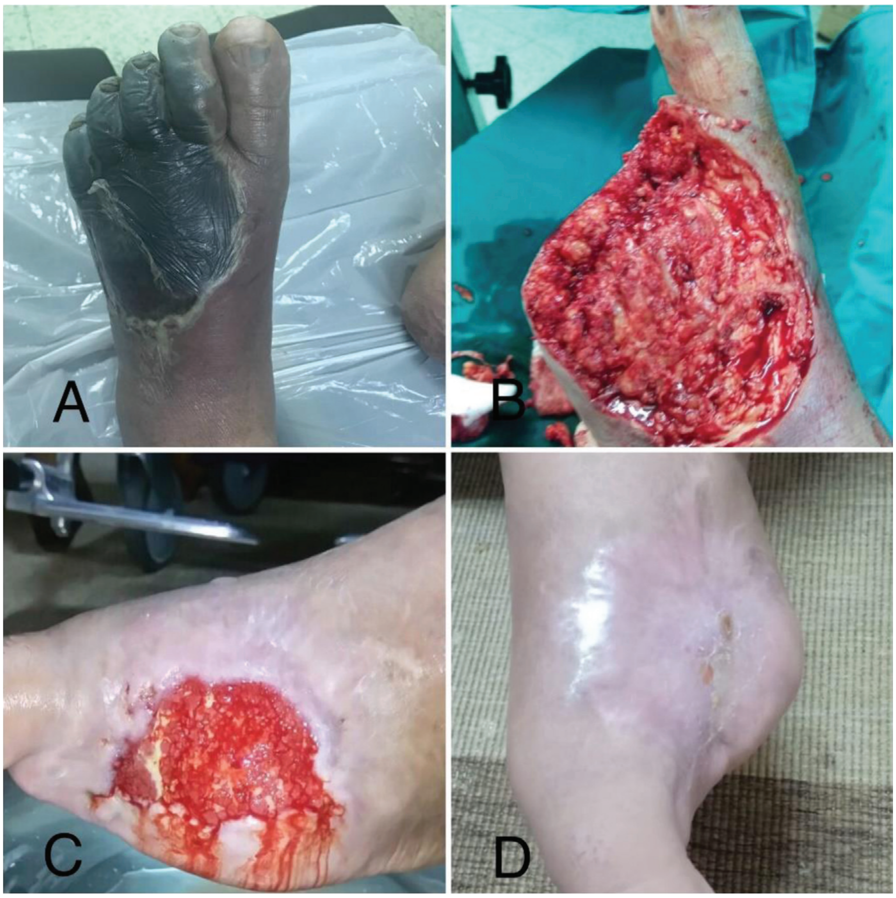
Between January 2016 and April 2017, 47 consecutive adult diabetic patients with CLI in the form of minor gangrene or grade 2 tissue loss according to the Wound, Ischemia, foot Infection score were operated upon for tibial vessels angioplasty in two centers in Egypt. Data of the 6 months follow-up period post-procedure was collected and analyzed. The patient's characteristics, medical history, and medical intake are detailed in Table 1 and reflect a very sick patient population. Procedural data (Table 2):

Figure 4

Ischemic gangrene of dorsum of the foot (a), surgical debridement 4 days after tibial angioplasty (b), split-thickness skin graft 3 months after wound epithelialization (c), foot salvage after complete healing (d).

29 (61.7%) patients were men and 18 (38.3%) patients were women. All the study patients were diabetics, 38.3% of the study patients (18 patients) were smokers, 57.4% (27 patients) had ischemic heart disease, 53.2% (25 patients) had hyperlipidemia, and 68.1% (32 patients) were hypertensive. Three (6.4%) of them had a history of cerebrovascular strokes, 34% (16 patients) were obese. Twenty-nine (61.7%) patients had dry gangrene, seven (14.9%) patients had extensive foot infection, and 11 (23.4%) patients with infective gangrene. Ipsilateral antegrade common femoral access was used in 31 (66%) patients, contralateral over the bifurcation antegrade access in 16 (34%) patients, while additional retrograde access was utilized in 12 (25.5%) patients due to vessel perforation or calcified cap of the lesion. Twenty-eight (59.6%) patients had multiple vessel recanalization, while 19 (40.4%) patients had single vessel recanalization. Forty (85.1%) patients underwent only balloon angioplasty and the remaining seven (14.9%) underwent additional bailout stenting for proximal tibioperoneal or anterior tibial arteries due to residual stenosis or dissection caused by calcification. Stenting was in patients with single runoff vessel to secure inline flow to pedal vessels. We performed surgical debridement in 46 (100%) patients. All the studied patients had been surgically debrided either before or just 2 days after endovascular intervention to confirm

Figure 5



Forefoot ischemic gangrene (a), surgical debridement 4 days after tibial angioplasty (b), wound healing by secondary intention with daily dressing (c), foot salvage after complete healing after 5 months (d)

Figure 6

Wound epithelialization 45 days after big toe amputation and debridement (a), split-thickness skin graft after wound healing (b), foot salvage after complete graft taking after 3 months (c).

adequate tissue perfusion or even had minor amputations, ranging from one toe to transmetatarsal amputation with full care in order not to disrupt the foot arch. Twenty-four (52.2%) patients underwent wound covering using STSG after wounds were granulating due to the large

Table 1 Demographic characteristics, risk factors, and clinical presentation of the study patients

Age (mean±SD) (years)	60±7
Sex [*n* (%)]	
Male	29 (61.7)
Female	18 (38.3)
Risk factors [*n* (%)]	
Smoking (yes)	18 (38.3)
Cerebrovascular strokes (yes)	3 (6.4)
Ischemic heart disease (yes)	27 (57.4)
Hyperlipidemia (yes)	25 (53.2)
Hypertensive (yes)	32 (68.1)
Diabetes mellitus (yes)	47 (100.0)
Obesity (yes)	16 (34.0)
Clinical foot lesions [*n* (%)]	
Dry gangrene (yes)	29 (61.7)
Infection (yes)	7 (14.9)
Infective gangrene (yes)	11 (23.4)

wound surface area to accelerate wound healing with graft uptake in 20 (83.3%) patients. Four (16.7%) patients rejected the grafts, two (50%) of them due to postoperative infection despite preoperative wound swabs were done, and the other two (50%) patients due to restenosis that necessitated redoing angioplasty. Ten (21%) patients required secondary surgical procedures to either control infection, debride necrotic tissues, remove osteomylitic bones, or major amputation (Table 2). All studied patients were followed up starting from immediately postsurgical debridement and then at 1, 3 and 6 months at the outpatient clinic. Table 3 showed the results of follow-up where healing signifies salvage with a progressive granulating wound bed or graft uptake and lost signifies nonsalvage in other words major amputation. After 1 month 43 (93.5%) patients were still patent, while three (6.5%) patients underwent major amputation by 1 month. After 3 months, 37 (80.4%) patients were patent (primary patency), three (6.5%) patients showed graft rejection, and six (13.0%) patients with restenosis, cdTLR was 2.2%. At the end of 6 months follow-up, 34 (74%) patients were primary patent, four (8.7%) patients underwent major amputation, and seven (15.2%) patients had restenosis with cdTLR (4.4%).

At the end of the follow-up period (6 months), 41 of the 46 (89.1%) studied patients had salvaged their limbs whereas five (10.9%) patients had lost their limbs and had major amputations [i.e. below knee amputation (BKA)] with 6-month total primary patency (74%) (Fig. 7). Thirty-seven (80.4%) patients had acquired wound healing either spontaneous with ordinary dressing modalities or after performing STSG and nine (19.6%) patients did not heal, five of them underwent major

Table 2 Procedural data

	N (%)
Access	
Ipsilateral antegrade	31 (66)
Contralateral antegrade	16 (34)
Added retrograde access	12 (25.5)
PTA access	7 (58.3)
DP access	5 (41.7)
Artery revascularized	
Peroneal	26 (55.3)
PTA	22 (46.8)
ATA	32 (68.1)
Three-vessel revascularization	9 (19.2)
Two-vessel revascularization	19 (40.4)
Single-vessel revascularization	19 (40.4)
Bailout DES stenting	7 (14.9)
ATA stenting	4 (57.1)
Tibioperoneal trunk stenting	3 (42.9)
Post-procedural pulse	
ATA	29/32 (90.1)
PTA	18/22 (81.8)
Debridement	46 (100)
Grafting	24 (52.2)
Secondary surgical intervention	10 (21)
Cause	
Fracture calcaneus	1 (10)
Infection	9 (90)
Type	
Major amputation	5 (50)
Minor amputation	3 (30)
Minor debridement	2 (20)
Time	
1 month	1 (10.0)
1 week	1 (10.0)
2 weeks	2 (20.0)
3 months	1 (10.0)
3 weeks	2 (20.0)
4 months	1 (10.0)
4 weeks	2 (20.0)
Complications of angioplasty	
Hypersensitivity	1 (2.2)
Died[a]	1 (2.2)
Hematoma	1 (2.2)
Renal insufficiency	2 (4.4)

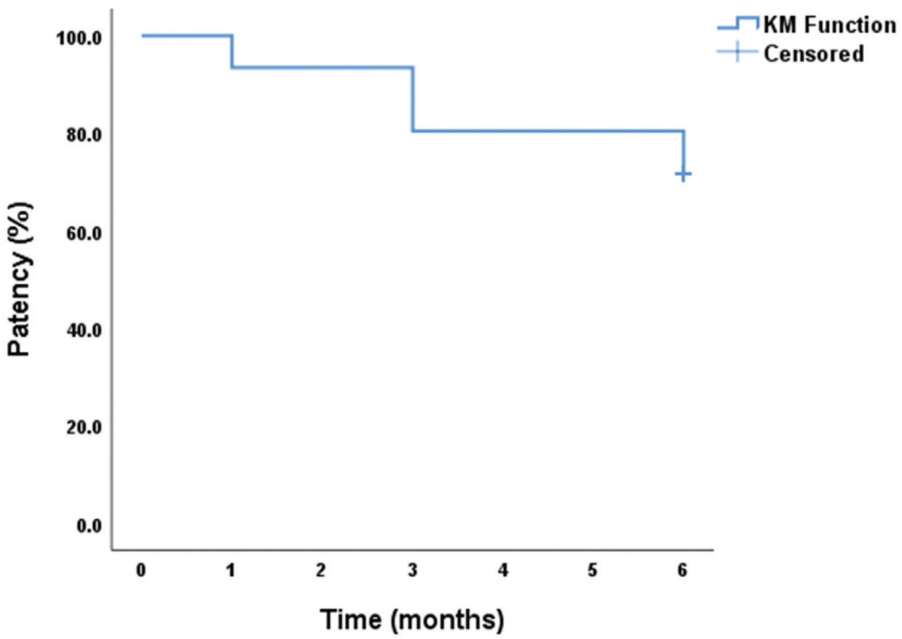
ATA, anterior tibial artery; DES, drug-eluting stent; DP, dorsalis pedis; PTA, posterior tibial artery. [a]One case died.

amputation and the other four patients rejected the graft (Fig. 8 and Table 4). Out of the 24 (52.2%) patients who needed skin graft 20 (83.3%) patients had taken the graft, while four (16.7%) patients rejected the graft. Limb salvage and wound healing were statistically significant (P=0.001 and $<$0.001 in sequential) in patients with patent revascularized tibial arteries compared with patients who showed restenosed or reoccluded vessels (Table 4). In our studied patients, 18 (39.1%) had single vessel revascularization, 15 (83.3%) had salvaged their limb with 6-month primary patency (66.7%), and 28

Table 3 Limb and wound state during follow-up

	Wound	*N* (%)	Patency [*N* (%)]
Immediate post-procedure	Clean wound bed	46 (100)	46 (100)
At 1 month	Healing	40 (87)	43 (93.5)
	Infected	3 (6.5)	
	Lost limb	3 (6.5)	
At 3 months	Healing	37 (80.4)	37 (80.4)
	Infected	3 (6.5)	
	Graft not taken	3 (6.5)	
	Lost limb	5 (6.5)	
At 6 months	Healing	37 (80.4)	34 (74)
	Graft not taken	4 (8.7)	
	Lost	5 (10.9)	

Figure 7



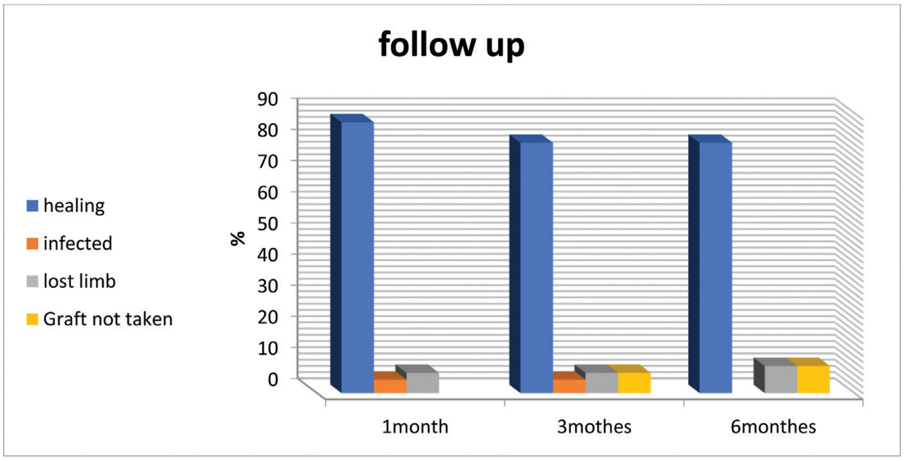
Kaplan–Meier survival curve for primary patency.

(60.9%) patients had more than one vessel recanalized, 26 (92.8%) of them had salvaged their limb with 6-month primary patency (84.6%). Despite limb salvage being superior in patients with multiple vessel recanalization compared with those with single vessel recanalization but it was not statistically significant (*P*=0.365; Table 5). One (2.2%) patient died due to myocardial infarction postoperatively, two (4.4%) patients had chronic renal insufficiency, and one (2.2%) had puncture site hematoma.

Discussion

CLI is the most common cause for major amputation and indication for peripheral revascularization. Most cases of CLI are diabetic patients; and the most pattern of complications they suffered is infected nonhealing ulcers [6]. This may be explained as diabetic patients are significantly less able to develop arterial collaterals [7]. Up to 40% of extremities with ischemic nonhealing ulcers, gangrenous digits, or rest pain may require a major amputation within 6 months of onset. If the CLI is not revascularized [8], percutaneous transluminal angioplasty has become the first line of revascularization for patients with CLI. The purpose of revascularization is to maintain sufficient blood flow to relieve rest pain and/or allow healing of the ischemic foot lesion [9]. This study is a retrospective observational study which included 47 diabetic patients of different age and sex with threatened limbs and predominantly tibial artery disease, many of whom were facing imminent amputation. Most of these patients had long-segment tibial artery occlusions rather than isolated stenoses. In our study, we excluded patients with multilevel arterial disease, and patients suffering from severe cardiac impairment with an EF of

Figure 8



Follow-up postprocedure events.

Table 4 Relation between primary patency and limb salvage

	Primary patency [*N* (%)]		*P* value
	Yes (*n*=33)	No (*n*=13)	
Limb salvage	33 (100.0)	8 (61.5)	0.001
Wound healing	32 (97.0)	5 (38.5)	<0.001

χ^2-Test and Fisher's exact test were used.

Table 5 Limb salvage in patients with single-vessel recanalization

	Single-vessel recanalization [*N* (%)]		*P* value
	Yes (*n*=18)	No (*n*=28)	
Limb salvage	15 (83.3)	26 (92.9)	0.365

Fisher's exact test was used.

less than 40%. Acutely ischemic patients as well as arteritic patients were also excluded due to different management options. The 47 patients met our inclusion criteria underwent tibial vessel revascularization. Surgical interventions were performed to all of them just before or immediately after revascularization in the form of debridement, toe amputation, and up to transmetatarsal amputation. Twenty-four (52.2%) patients had large granulating wounds after variable periods of the first surgical intervention and STSGs were performed and followed up. The main outcome of our study is that a successful below-the-knee angioplasty procedure saves a very high percentage of limbs at follow-up in selected patients with ischemic diabetic foot and isolated tibial, peroneal, or foot-artery disease. The limb salvage rate was 80.4% with a restenosis rate of 26%. Ferraresi *et al.* [3] reported that the limb salvage rate was 93% despite a US restenosis rate of 42%. This arouses the attention to the concept that long-term complete patency of the treated vessel is less important as the recanalization temporarily improves blood flow to the foot that aids in eradicating and healing ulcers. Progressive tissue healing decreases oxygen requirement; less blood flow is generally needed to keep tissue intact and to maintain the limb asymptomatic [10]. One of the main pros of the endovascular therapy is its ability to 'navigate' through the patient's infra-popliteal vascular tree, offering the probability of treating more than one tibial vessel that could be associated with better clinical outcomes; however, single vessel revascularization may achieve the same target. In our study, we found overall limb salvage rate was 89.1% in all studied patients, in 28 patients (60.9%) underwent multiple vessel recanalization limb salvage rate was 92.9% which was higher than salvage rate (83.3%) achieved in18 patients (39.1%) with single vessel revascularization but not statistically significant this is may be due to the small sample of patients. Acin *et al.* [11] reported that procedures in which more than one patent tibial artery was obtained (runoff>1) had similar ankle-brachial index improvement than those in which a single outflow (runoff 1) vessel was reperfused, but did not show any more clinical or hemodynamic improvement during follow-up when it was compared with (runoff 1) group. According to these results and other data, we could declare that obtaining a single patent tibial artery to the foot is enough to achieve good clinical results. Regarding tibial artery stenting despite this is not one of our study endpoints as this technique was a bailout procedure to secure distal perfusion and represent small sample to judge, in our seven patients 6-month primary patency was 100%. The other side reperfused ischemic ulcers is how to care with it, which represents a major postprocedure problem due to prolonged tissue healing time and the frequent need for other associated techniques on the wound. Delayed healing is especially important in patients with diabetes mellitus; this makes us eager to use wound coverings like STSGs after wound epithelialization to accelerate the healing process. We achieved successful wound healing in 37 (80.4%) patients, 24 (64.9%) of them underwent wound covering with STSG with graft uptake in 20 (83.3%) patients. Mahmoud *et al.* [12] prospectively studied patients with STSG versus conservative wound care for diabetic foot wounds and found a statistically significant reduction in mean hospital stay and healing time for those patients treated with STSG. Anderson *et al.* [13] concluded that autologous STSG are a safe and reliable alternative for the treatment of nonhealing diabetic foot and leg wounds after revascularization. According to the results in this study, we suggest it is mandatory to obtain a direct straight line to the foot through at least one tibial artery with preference to be anatomically related to the wound, but if not go through the easier tibial vessel to-treat, and STSG is a safe and reliable option to achieve fast wound healing.

Study limitations

We acknowledge several limitations of our study. One of them is that our study was conducted as a retrospective, observational study. Also, one of the limitations was the small patient sample with a short-term follow-up period. We recommend the future studies to be conducted as a prospective study with a larger patient sample and longer follow-up period to provide more information about long-term patency and relation to maintain wound healing and limb salvage.

Conclusion

STSG can be considered a reliable option for achieving wound healing in diabetic foot patients with below-the-knee PVD after successful revascularization and proper wound debridement. Long-term patency of revascularized below-knee vessels may be not essential to maintain limb salvage; however, it is mandatory to keep them patent as long as there is still healing wound to achieve limb salvage. Single vessel recanalization was dependable to achieve the target of tibial arteries angioplasty when there were no options to revascularize the other neighboring vessels. Establishing multidisciplinary team to manage CLI in diabetic patients was essential to offer the optimum care for CLI patients.

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Conflicts of interest

There are no conflicts of interest.

References

1 Jörneskog G. Why critical limb ischemia criteria are not applicable to diabetic foot and what the consequences are. Scand J Surge 2012; 101:114–118.

2 Norgren L, Hiatt WR, Dormandy JA, Nehler MR, Harris KA, Fowkes FG. Inter-society consensus for the management of peripheral arterial disease (TASC II). J Vasc Surg 2007; 45:S5–S67.

3 Ferraresi R, Centola M, Ferlini M, Da Ros R, Caravaggi C, Assaloni R, *et al.* Long-term outcomes after angioplasty of isolated, below-the-knee arteries in diabetic patients with critical limb ischaemia. Eur J Vasc Endovasc Surg 2009; 37:336–342.

4 Manzi M, Palena LM, Cester G. Revascularization of Tibial and Foot Arteries: Below the Knee Angioplasty for Limb Salvage, Angioplasty, Various Techniques and Challenges in Treatment of Congenital and Acquired Vascular Stenoses, Dr. Thomas Forbes (Ed.), ISBN: 978-953-51-0084-3, InTech, Available from: http://www.intechopen.com/books/angioplasty-various-techniques-and-challenges-intreatment-of congenital-and-acquired-vascular-stenoses/revascularization-of-tibial-and-foot-arteries-bellowthe-knee-angioplasty-for-limb-salvage.

5 Rose JF, Giovinco N, Mills JL, Najafi B, Pappalardo J, Armstrong DG. Split-thickness skin grafting the high-risk diabetic foot. J Vasc Surg 2014; 59:1657–1663.

6 Uccioli L, Gandini R, Giurato L, Fabiano S, Pampana E, Spallone V, *et al.* Long-term outcomes of diabetic patients with critical limb ischemia followed in a tertiary referral diabetic foot clinic. Diabetes Care 2010; 33:977–982.

7 Weihrauch D, Lohr NL, Mraovic B, Ludwig LM, Chilian WM, Pagel PS, *et al.* Chronic hyperglycaemia attenuates coronary collateral development and impairs proliferative properties of myocardial interstitial fluid by production of angiostatin. Circulation 2004; 109:2343–2348.

8 Tefera G, Hoch J, Turnipseed WD. Limb-salvage angioplasty in vascular surgery practice. J Vasc Surg 2005; 41:988–993.

9 Ouriel K. Peripheral arterial disease. Lancet 2001; 358:1257–1264.

10 Soder HK, Manninen HI, Jaakkola P, Matsi PJ, Rasanen HT, Kaukanen E, *et al.* Prospective trial of infrapopliteal artery balloon angioplasty for critical limb ischemia: angiographic and clinical results. J Vasc Interv Radiol 2000; 11:1021–1031.

11 Acín F, Varela C, López de Maturana I, de Haro J, Bleda S, Rodriguez-Padilla J. Results of infrapopliteal endovascular procedures performed in diabetic patients with critical limb ischemia and tissue loss from the perspective of an angiosome-oriented revascularization strategy. Int J Vasc Med 2014; 2014:270539.

12 Mahmoud SM, Mohamed AA, Mahdi SE, Ahmed ME. Split-skin graft in the management of diabetic foot ulcers. J Wound Care 2008; 17:303–306.

13 Anderson JJ, Wallin KJ, Spencer L. Split thickness skin grafts for the treatment of non-healing foot and leg ulcers in patients with diabetes: a retrospective review. Diabet Foot Ankle 2012; 3:10204.