The role of open access endovascular revascularization in treatment of critically ischemic lower limbs: a three-center 1-year experience

Sameh Moustafa[a], Adel Elhusseiny Kamhawy[b], Amr Salem[c]

[a]Department of Surgery, Vascular Surgery Unit, Faculty of Medicine, Alexandria University, Egypt, [b]Vascular Surgery Department, Faculty of Medicine, Tanta University, Tanta, Egypt, [c]Department of Experimental and Clinical Surgery, Medical Research Institute, Alexandria University, Alexandria, Egypt

Correspondence to Sameh Moustafa, MD, Department of Surgery, Vascular Surgery Unit, Faculty of Medicine, Alexandria University, Al Kartoom Square, Raml Station, Al Azareta Campus, Alexandria, 21500, Egypt.
Tel: +20 100 290 7922;
e-mail: mostsam73@hotmail.com

Received: 6 February 2021
Revised: 25 February 2021
Accepted: 9 March 2021
Published: 12 October 2021

The Egyptian Journal of Surgery 2021, 40:600–609

Introduction
Chronic limb-threatening ischemia (CLTI) is commonly produced by multilevel arterial tree affection. To correct its effect, multisegment revascularization was adopted. The use of hybrid revascularization includes the use of an open access to accomplish the endovascular part of the procedure. Sometimes, for technical issues, open access is used for only angioplasty. In thrombectomy, for acute ischemia, residual chronic lesion angioplasty is done. This, also, entails the use of open access for angioplasty.
Aim
To report and evaluate three-center work in open access endovascular therapy for lower limb CLTI and acute thrombotic ischemia.
Patients and methods
This prospective study included patients admitted to Vascular Surgery Unit, Faculty of Medicine, Alexandria University, Department of Vascular Surgery, Faculty of Medicine, Tanta University, and Department of Experimental and Clinical Surgery, Medical Research Institute, Alexandria University, from June 1, 2018, to May 31, 2019, treated by different endovascular modalities done through open surgical access and followed for 1 year.
Results
A total of 116 patients were included, comprising 86.2% men and 13.8%women. The mean±SD age was 59.74±7.82 years. A total of 98 (84.5%) patients had CLTI and 18 (15.5%) had acute thrombotic ischemia. All acute patients had hybrid thrombectomy and completion angioplasty with excellent outcome. For patients with CLTI, 30 (25.9%) had open access angioplasty only and the rest 86 (74.1%) patients had hybrid endosurgical revascularization. Technical success was 94.8% for all cases. The primary and secondary patency rates were 67.6 and 76.5%, respectively, at 6 months and 52.7 and 62.6%, respectively, at 1 year, with an acceptable limb salvage rate of 91.2% at 1 year.
Conclusion
Open access endovascular procedures are feasible maneuvers allowing multisegment arterial disease treatment in both chronic and acute occlusions, offering good tools for the surgeon to minimize invasive approaches with acceptable patency and good limb salvage but should be reserved for critical ischemia owing to their complex nature.

Keywords:
angioplasty, critical ischemia, open access, three centered

Egyptian J Surgery 40:600–609

1110-1121

Introduction

Chronic limb-threatening ischemia (CLTI) is a final-stage clinical scenario of peripheral arterial disease (PAD) associated with a high incidence of limb loss as well as decreased overall survival because of the related comorbidities, for example, diabetes mellitus, hypertension, and chronic kidney and pulmonary diseases. It is estimated to affect 50–100 per 100 000 population in Western countries, with marked health care resources consumption [1].

Regarding patient activity, the presence of single-segment arterial occlusive disease usually produces intermittent claudication or asymptomatic disease. It, usually, does not result in the limb-threatening chronic ischemia (CLTI), which requires a pathologic anatomy in the form of the typical multiple-level occlusive disease or, to a less extent, the diffuse tibial arterial disease [2].

The optimal management of critical limb ischemia owing to multilevel arterial disease is revascularization

with the aim of limb salvage. This entails correction of a single level or, better, all levels of occlusion according to the clinical judgement. Nearly 25% of patients experiencing multilevel arterial occlusions require correction of both aortoiliac and infrainguinal lesions [3]. In such cases, the classical aortofemoral bypass in addition to infrainguinal arterial grafting represents an effective option to solve the patients' problem in the context of limb salvage [4]. If done simultaneously, they offer a single-session procedure with no need of rehospitalization and avoiding dissection in an area of previous operative scar. However, they carry as high as 19% mortality and 61% morbidity, if done this way [5].

As an alternative with comparable limb salvage, the early work of Dougherty *et al.* [6] reported much lower morbidity (11%) and mortality (1.4%) rates with the use of combination of open arterial reconstruction and endovascular intervention.

Marin *et al.* [7] were the first to report the use of open arterial access to deliver stent grafts endoluminally for critical limb ischemia management in 1994. The same idea was adopted successfully in endovascular abdominal aortic aneurysm repair (EVAR) using direct femoral artery cut-down to introduce large-caliber stent delivery systems which cannot be applied percutaneously. This was considered the prototype hybrid approach considering an open access for endoluminal aim [8].

One of the common uses of open access endovascular intervention is the hybrid revascularization which entails the use of direct arterial exposure created initially as part of open surgical reconstruction for endovascular treatment of either an inflow and/or outflow segment of the segment treated surgically. Both approaches are done simultaneously during this hybrid technique. It is the lesion anatomy which helps decide whether to use open surgery endovascular treatment, and TASC classification is the standard guide for such decision [9]. When a lesion is recommended for open revascularization at certain arterial level and another one at another level amenable to angioplasty in the same limb suffering critical ischemia, hybrid revascularization is preferred. The open surgical wound guarantees an open access for the complementary inflow and/or outflow endovascular management [10].

Another application of the open access endovascular intervention is its use in treatment of acute thrombotic limb ischemia. In these cases, it is used as an access for complementary revascularization after thrombectomy using its arterial exposure for doing angiogram and dealing with any residual arterial lesion [11], for example, superficial femoral artery (SFA) and popliteal balloon dilatation for residual chronic lesions revealed by control angiogram after femoral thrombectomy.

In certain situations, surgical femoral exposure is required as the primary access for endovascular treatment. This occurs when a very proximal SFA lesion reaching close to its ostium that renders access sheath insertion and ballooning at this level difficult or even impossible. Such situation can be dealt with by going through a cross-over femoral or transbrachial approach. However, when you need to treat down to the ankle and when you deal with a proximal iliac lesion requiring correction, femoral artery open access is solution.

After the failed use of ultrasound and fluoroscopy guidance for a proposed percutaneous access, open access through arterial cut-down can be applied whenever puncture is difficult or impossible. This was reported as case reports for retrograde pedal access for limb salvage [12]. However, the routine use of such open pedal artery access for retrograde angioplasty was adopted by others [13].

In this study and for 1 year, in three different university hospitals, we tried to report any endovascular procedure using an open access to treat critical lower limb ischemia which looks appealing and feasible to vascular surgeons who master both techniques.

Aim

The aim of this study was to report a three-center experience in endovascular treating procedures done through an open surgical arterial access in the management of CLTI as well as cases of acute thrombotic ischemia of the lower limbs regarding the following:

(1) Indications and incidence in 1-year period.
(2) Feasibility of the technique.
(3) Outcome and complications.

Patients and methods

This prospective study included patients admitted to Vascular Surgery Unit of Alexandria University Faculty of Medicine, Tanta University Faculty of Medicine,

and Alexandria University Medical Research Institute in the period from June 1, 2018, to May 31, 2019, having the following inclusion criteria:

(1) CLTI owing to multilevel arterial occlusive disease requiring hybrid revascularization to ensure adequate inflow and/or outflow for open surgical procedure.
(2) CLTI owing to infrainguinal arterial occlusive disease with affection of crural arteries in addition to common femoral artery (CFA) or proximal SFA lesions, requiring femoral cut down.
(3) Acute thrombotic lower limb ischemia indicated for thrombectomy (Rutherford grade II) where thrombectomy could be completed by diagnostic angiography and residual chronic lesion angioplasty.
(4) Open tibial access retrograde approach to treat CLTI after failed percutaneous tibial artery puncture.

All patients with chronic lower limb ischemia included in this study were categorized as Rutherford grades IV and V.

The following patients were excluded from the study:

(1) Major gangrene indicated for major lower limb amputation (Rutherford class VI).
(2) Acute irreversible lower limb ischemia indicated for major amputation (Rutherford grade III).
(3) Patients with CFA and/or SFA proximal lesions without infragenicular affection (that could be accessed through cross-over femoral or transbrachial approaches).
(4) Patients experiencing thrombotic lower limb ischemia treated by thrombectomy with no residual chronic lesion in control angiogram.
(5) Acute embolic lower limb ischemia.
(6) Life-threatening limb infection and patients unfitness for anesthesia.
(7) Claudicant patients.
(8) Patients having TASC B and C lesions [9] in arterial segments other than the one planned for open revascularization part of the planned hybrid technique.

The patients of this study were subjected to the following:

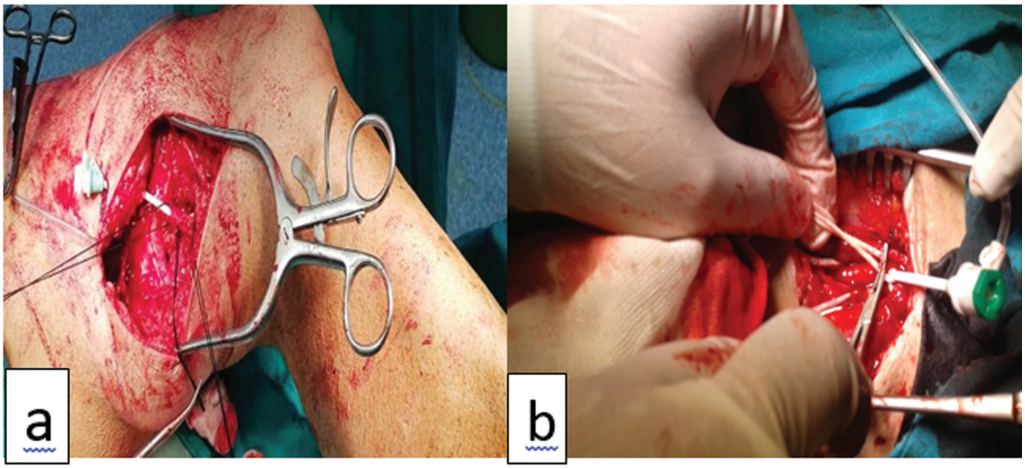
(1) Full history taking.
(2) Thorough clinical evaluation.
(3) Laboratory investigations including the following:
    (a) Complete blood count.
    (b) Blood glucose level.
    (c) Renal and liver function tests.
    (d) Plasma lipid profile.
(4) ECG and plain chest radiogram.
(5) Respiratory function tests when indicated.
(6) Duplex ultrasound examination of the complaining limb for the following:
    (a) Arterial tree evaluation including inflow and runoff segments.
    (b) Saphenous vein mapping.
(7) Computed tomography angiography of the abdominal aorta and both lower limb arterial trees.
(8) This study was conducted after approval of Institutional Ethics Committee, and the patients signed an informed consent before being enrolled in the study. The study was done according to the Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.
(9) Procedures: after signing informed consents, all study patients were treated by endovascular therapy managing either part of or all the target lesions through an open surgical arterial cut down and exposure. Such exposures were done either as part of hybrid revascularization procedure or as an intended access point to get near to the target lesions. In all cases, a 6 F sheath was used for access except in cases of retrograde pedal access where a 4 F sheath or a sheathless approach was used instead. Sheath was introduced through the surgical wound skin flap to avoid applying tension on the arterial wall during manipulations (Fig. 1a). However, direct arterial wall insertion was used in some cases and sometimes through a bypass graft (Fig. 1b).

In patients treated by hybrid techniques, presurgical puncture and wiring were done with the endovascular part of the procedure done first (Fig. 2a, b). After that, the surgical part was done (bypass or endarterectomy) using puncture as an arteriotomy location site to complete the procedure. In other patients, surgical part of the procedure was done first with closure of the arteriotomy done before puncture to allow better control of bleeding during the endovascular part (postsurgical puncture) (Fig. 2c, d). However, in few cases, transarteriotomy sheathing was done.

In open access angioplasty without surgical part, punctures were closed by direct interrupted sutures with no need for compression or closure devices.

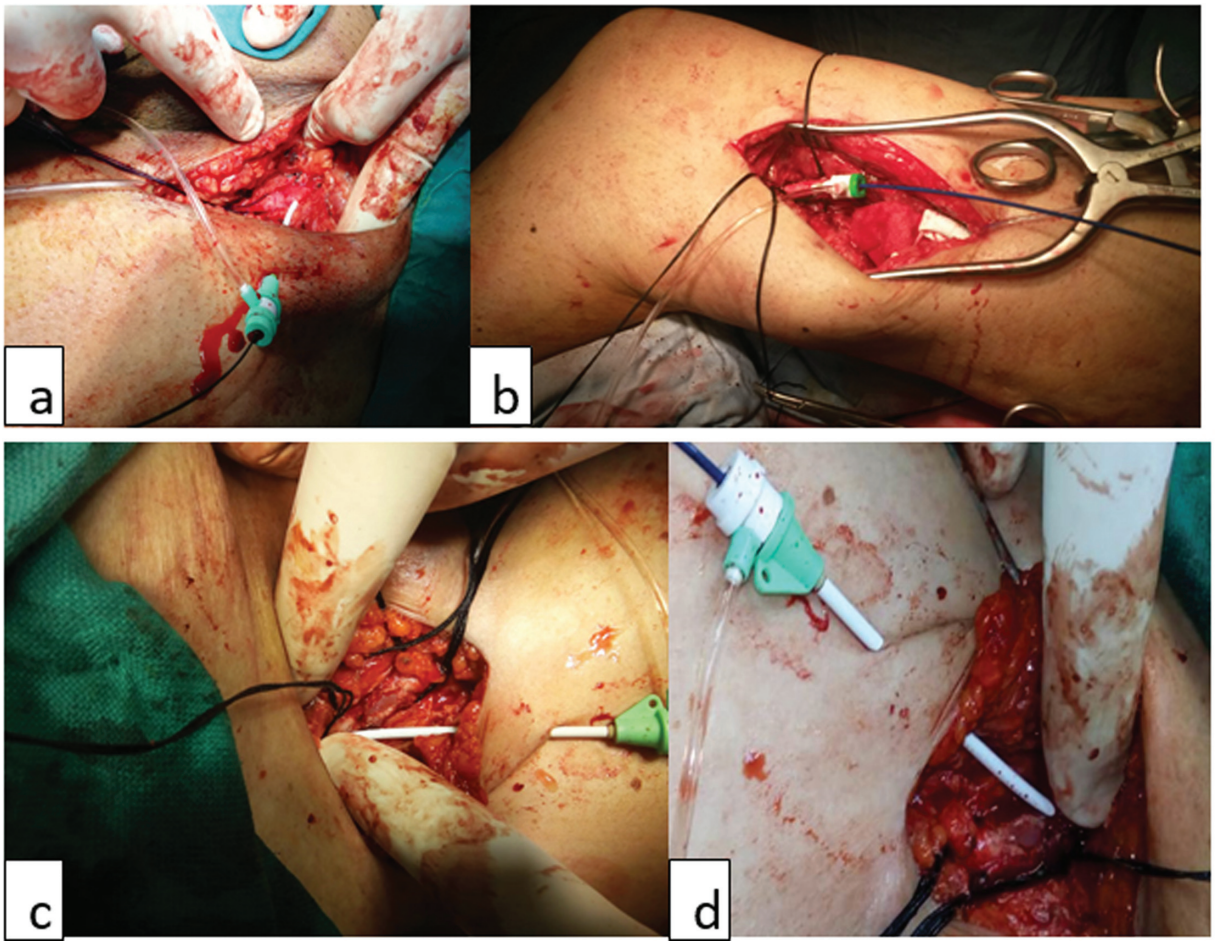
The choice of the lesions treated by angioplasty was guided by the TASC II recommendations to treat PAD, that is, all were TASC A or B, whereas the arterial segments treated by open surgery were classified C and D [9].

Figure 1



Angioplasty sheath inserted for open access (a): through the wound skin flap. (b) Direct arterial insertion.

Figure 2



(a) Presurgical wiring of the femoral artery for iliac PTA for femoropopliteal bypass inflow. (b) Presurgical wiring of popliteal artery for tibial PTA before femoropopliteal bypass. (c) Postsurgical wiring of femoral artery after endarterectomy and patching for complementary iliac PTA. (d) Postsurgical femoral access after reconstruction and patching for distal PTA. PTA, percutaneous transluminal angioplasty.

Patients were followed immediately postoperative and 3 months, 6 months, and 1 year afterward for clinical outcome, patency (using duplex study), reintervention, complications, and limb salvage.

Results

This prospective study included 116 adult patients, comprising 100 (86.2%) males and 16 (13.8%)

females. Their age ranged from 46 to 80 years, with mean±SD age of 59.74±7.82 years. Patients' comorbidities and history of previous vascular interventions are listed in Table 1.

The indication of revascularization was chronic CLTI in the form of ischemic tissue loss (Rutherford's V) in 98 (84.5%) patients in addition to acute ischemia femoral artery thrombosis in 16 (13.8%) patients and acute postoperative femoropopliteal vein graft occlusion in two (1.72%) (Table 2).

Table 1 Distribution of the studied cases according to comorbidities and previous vascular intervention (*N*=116)

Comorbidity	*n* (%)
Diabetes mellitus	108 (93.1)
Essential hypertension	82 (70.7)
Ischemic heart disease	42 (36.2)
Chronic pulmonary disease	18 (15.5)
Chronic kidney disease	8 (6.9)
Smoking	84 (72.4)
Heart failure	14 (12.1)
Previous contralateral major amputation	10 (8.6)
Previous vascular procedure	16 (13.8)
Ipsilateral femoropopliteal bypass few days before	2 (1.72)
Contralateral PTA	4 (3.45)
Ipsilateral PTA	4 (3.45)
Contralateral femoropopliteal bypass	3 (2.59)

PTA, percutaneous transluminal angioplasty.

According to patients' imaging, patients presented with acute lower limb ischemia had abrupt CFA occlusion with poor or no runoff (Fig. 3a) in 16 patients, whereas two other patients had acute femoropopliteal bypass graft occlusion in the early postoperative period and were treated immediately on duplex basis owing to critical condition of the patient limb.

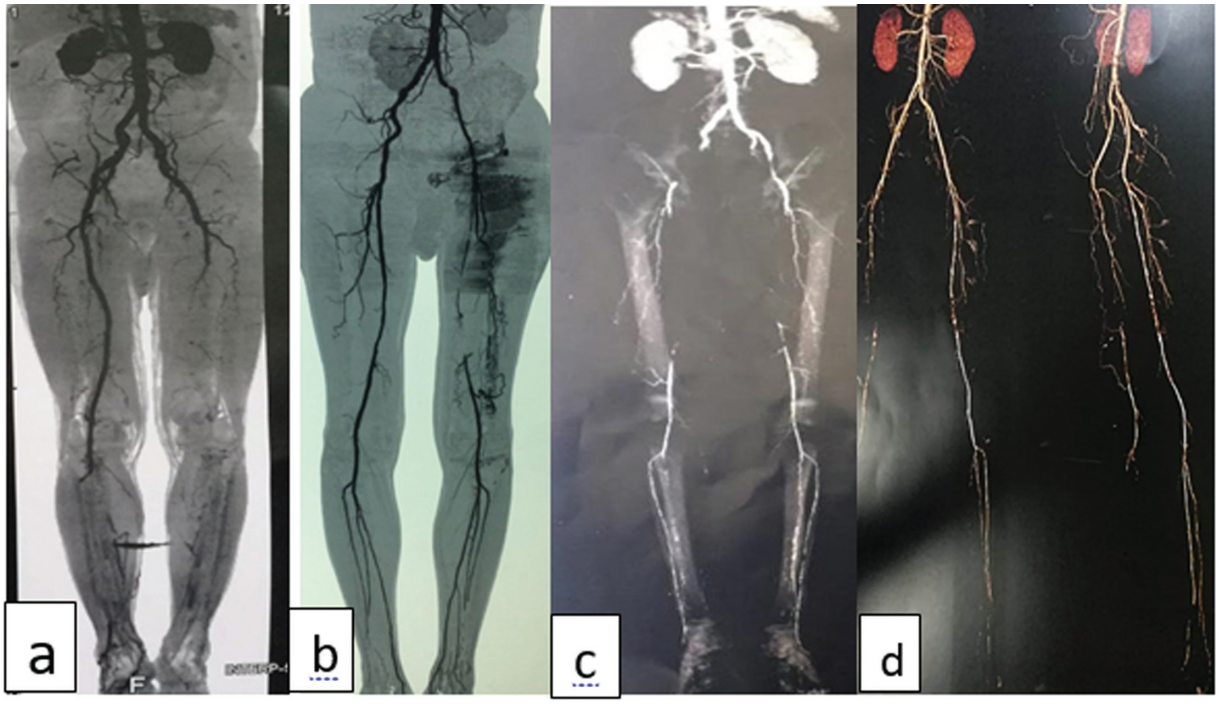
On the contrary, chronically ischemic limb patients had multilevel atherosclerotic arterial occlusive disease commonly affecting the SFA in 100 (86.2%) patients in the form of 58 stenosis and 42 total occlusions. The second commonly affected segment was the infragenicular one in 68 (58.6%) patients followed by the iliac segment in 48 (41.4%) patients in the form of 30 stenoses and 18 common iliac artery occlusions.

Table 2 Distribution of the studied cases according to clinical picture

Clinical picture	*n* (%)
Presentation (*N*=116)	
Toe gangrene	53 (45.7)
Foot ulcer	34 (29.3)
Acute ischemia	18 (15.5)
Toe gangrene+foot ulcer	11 (9.4)
Rutherford category V (CLTI patients)	98 (84.5)

CLTI, chronic limb-threatening ischemia.

Figure 3



Angiographic presentations. (a) Acute left femoral occlusion with poor run-off. (b) Chronic left iliac stenosis+SFA occlusion. (c) Chronic bilateral iliac occlusive lesions+SFA occlusion+tibial artery disease (left side was the complaining one). (d) Chronic SFA stenosis starting from its origin down to popliteal artery+tibial arteries disease. SFA, superficial femoral artery.

The commonest lesion combination, in these patients, was that including both SFA (32 occlusions and 34 stenoses) and the tibial arteries in 66 (56.9%) patients. The second common combination was that of iliac lesions and SFA in 40 (34.5%) patients and that of iliac, SFA, and tibial arteries together in 20 (17.2%) patients (Fig. 3).

All study patients were treated by angioplasty through an open surgical access using different maneuvers (Table 3). This, when compared with the total number of angioplasty cases done in the centers involved in this study, represents, ~15–19% of endovascular treatment procedures for PAD done per year. In 30 (25.9%) patients, open access angioplasty without open surgical reconstruction (endovascular only) was done. In seven (6%) of them, this was done to treat osteal (proximal) SFA stenotic lesions combined with tibial distal lesions for better accessibility and wire control than in cross-over femoral access. In another 19 (16.3%) patients, this approach was done for bidirectional angioplasty where after femoral exposure the surgeon went up for iliac angioplasty then down for SFA and tibial angioplasty (Fig. 4). In two patients, open ankle anterior tibial access was done after failure of the percutaneous one for retrograde tibial artery access for angioplasty.

A total of 86 (74.1%) patients were offered hybrid revascularization, and the endovascular part was done through surgical arterial cut down for bypass in 48 (41.4%) patients and for femoral endarterectomy in 20 (17.2%) patients to improve either the surgical revascularization inflow, outflow, or both for patients with CLTI (Fig. 5).

A total of 18 (15.5%) patients of these hybrid category were treated for acute thrombotic ischemia; 16 (13.8%) of them had hybrid femoral thrombectomy and outflow angioplasty with complementary femoral endarterectomy in 14 (12.07%) of them. Two (1.72%) patients of this group had a combination of femoropopliteal graft thrombectomy and popliteal and tibial angioplasty as an outflow treatment. All treated acutely ischemic limbs had 100% technical success and good clinical outcome in the form of disappearance of the ischemic symptoms. No postoperative complication was reported in this category except five groin wound inflammation and one patient who had residual ankle drop despite being successfully revascularized (Fig. 6).

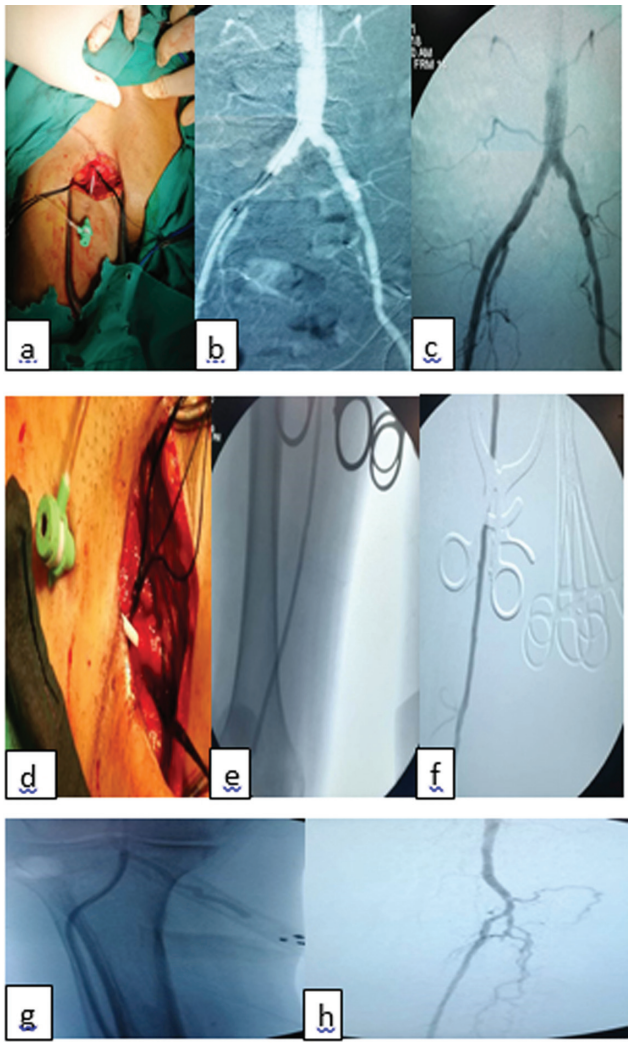
In all study patients, failure to pass the lesion occurred in six patients rendering a technical success of 94.8% (110 patients). In the first 4 months postoperatively, five above-ankle amputations were reported owing to bypass graft removal after infection and secondary hemorrhage. Three femoropopliteal bypass graft occlusion and foot gangrene treated by above-knee amputation were reported in this period, rendering the total number of major limb amputation of eight patients, 4 months postoperatively. In the first 4

Table 3 Distribution of the studied cases according to procedures (*N*=116)

Procedures	*n* (%)
Site of access	
Femoral	90 (77.6)
Poplitial	20 (17.2)
Tibial ankle retrograde	2 (1.72)
Femoral and Popliteal	4 (3.4)
Open access purpose	
Angioplasty only	30 (25.9)
Hybrid revascularization	86 (74.1)
Open surgical part of the hybrid revascularization done	
CFA endarterectomy for CLTI	20 (17.2)
Femoral pop bypass	47 (40.51
Aorto–bifemoral bypass	1 (0.86)
Thrombectomy for acute ischemia	18 (15.5)
Complementary CFA endarterectomy after thrombectomy for acute ischemia	14 (12.07)
Angioplasty segments treated	
Iliac balloon dilatation (no stenting)	40 (34.5)
SFA	66 (56.9)
Popliteal	50 (43.1)
Tibial	68 (58.6)
Iliac stenting	32 (27.6)

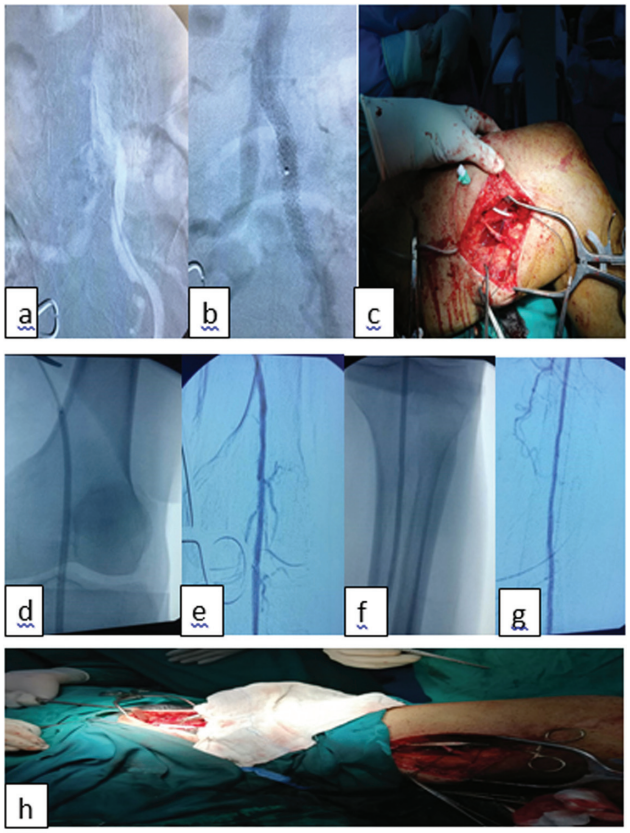
CFA, common femoral artery; CLTI, chronic limb-threatening ischemia; SFA, superficial femoral artery.

Figure 4



Bidirectional open access angioplasty. (a) Femoral cut-down for iliac access. (b) Iliac balloon angioplasty. (c) Iliac postdilatation with no stent. (d) Accessing SFA through the same femoral cut-down. (e) SFA balloon angioplasty. (f) SFA postdiltation. (g) Anterior tibial (ATA) angioplasty. (h) ATA postdilatation. SFA, superficial femoral artery.

Figure 5



Hybrid femoropopliteal bypass with iliac stenting and outflow angioplasty. (a) Common iliac artery stenosis accessed via femoral artery cut-down. (b) Iliac postdilatation and stenting. (c) Popliteal artery open access. (d) Popliteal balloon dilataion. (e) Popliteal artery postdilatation. (f) Peroneal artery balloon angioplasty. (g) Peroneal postdilatation. (h) Femoropopliteal bypass graft.

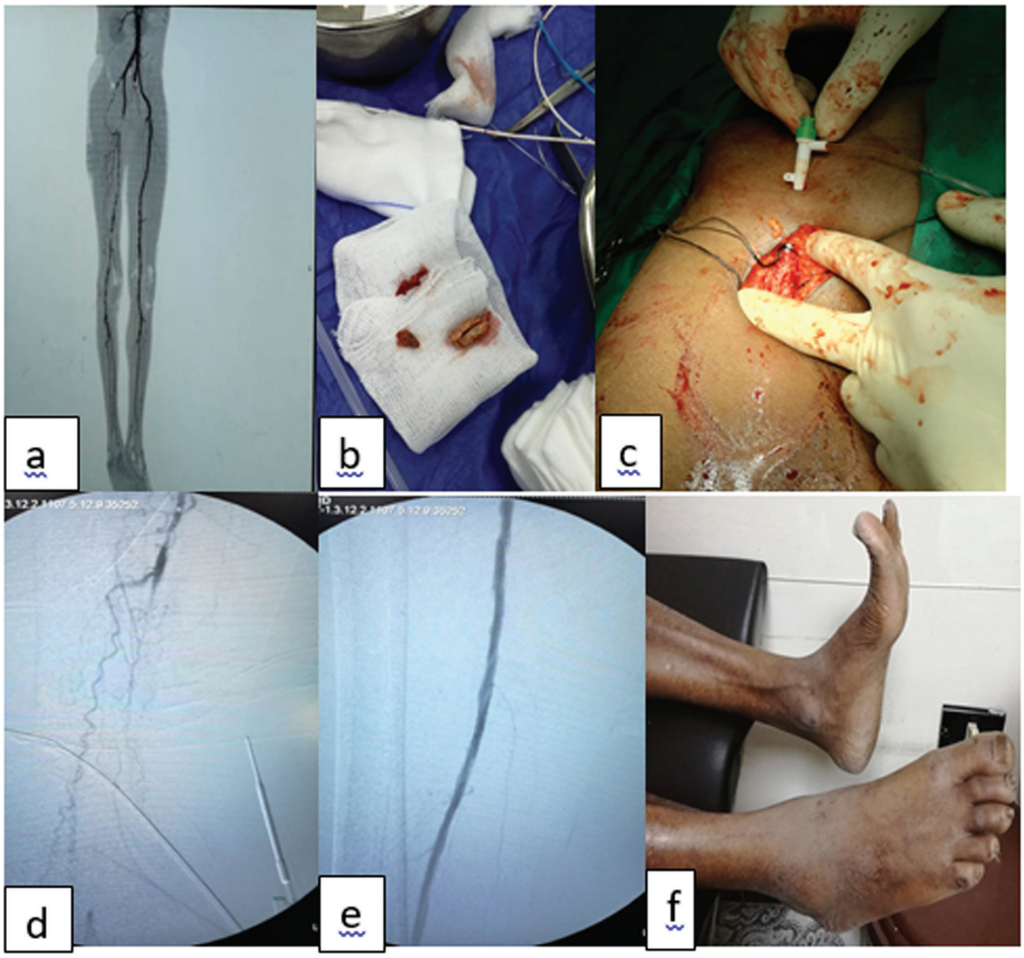
months, failure of foot lesion healing was encountered in nine (8.2%) patients owing to restenosis at the proximal femoropopliteal anastomosis, distal anastomosis, or both but with still patent grafts. These lesions were treated by redo-balloon dilatation through cross-over contralateral approach with successful outcome, rendering a 4-month primary patency of 84.5% and secondary patency of 92.7%. Clinical improvement was observed in this period in the form of disappearance of rest pain and healing of ischemic foot lesions after complementary debridement, toe amputations, and forefoot closed amputations. Thus, the 4-month limb salvage was estimated to be 92.7%. Patients' follow-up continued for 1 year postoperatively. Outcome and complications are shown in Table 4.

Discussion

Many reports stated that increased patient age is reciprocally related to PAD incidence increase in both sexes with no clear data supporting sex predominance [14]. In this study, the mean age of patients was 59.14 years, and 86.2% of them were males. This male predominance might be related to the advanced nature of the disease in the studied patients, that is, 84.5% CLTI and 15.5% thrombotic acute limb ischemia (ALI) with multilevel arterial involvement in both. With such complex lesions, in the current study, it is expected to have high incidence of diabetes mellitus (93.1%) and smoking (72.4%) with their significant aggravating effects on both disease progression risk of limb loss [15].

All study patients had atherosclerosis localized most commonly in the SFA followed by crural arteries and then iliac segment affection in different combinations. Disease localization matches those of many reports studying PAD whether for claudicant patient or those with critical limb ischemia [16–18]. Although

Figure 6



Acute femoral artery thrombosis treated by hybrid thrombectomy-balloon dilatation. (a) CT angiography. (b) Part of the thrombus removed and endarterectomy cast. (c) Femoral antegrade sheath after closure by a vein patch. (d) Predilatation SFA angiogram. (e) Postdilatation angiogram. (f) Saved limb 2 weeks postoperatively with residual ankle drop. CT, computed tomography; SFA, superficial femoral artery.

Table 4 Study outcome and complications

Outcome and complications	4 months post-operatively (patients No.=110)	6 months post-operatively (patients No.=102)	1 year post-operatively (patients No.=91)
Lost follow-up	–	–	10 (9.8%)
Mortality due to cardiovascular events	–	8 (7.2%)	1 (0.9%)
Bypass graft infection	5 (4.5%)	–	–
Bypass graft occlusion	3 (2.7%)	–	8 (8.7%)
Angioplasty restenosis and occlusion	9 (8.1%)	16 (15.7%)	10 (11%)
	Treated by successful redo angioplasty	Managed conservatively	Managed conservatively
Leg hematoma	4 (3.6%)	–	–
	Managed conservatively		
Groin wound inflammation	6 (5.5%)	–	–
Limb loss	8 (7.3%)	–	–
1ry patency	93 (84.5%)	69 (67.6%)	48 (52.7%)
2ry patency	102 (92.7%)	78 (76.5%)	57 (62.6%)
Limb salvage	102(92.7%)	94(92.2%)	83 (91.2%)

polysegmental arterial disease was reported in about 2/3 of all symptomatic PAD [19], the link between CLTI and multilevel atherosclerosis, as well as, tibial artery involvement was found typical and significant [20].

In the current study, acutely ischemic limbs (15.5%) were treated by a combination of thrombectomy and underlying lesion balloon angioplasty. This approach was adopted by the working teams instead of catheter-directed thrombolysis. This preference was attributed to

either unavailability of the required equipment or the critical clinical presentation (Rutherford's class IIb). We reported a 100% technical success and one case postoperative residual ankle drop, no mortality, and no limb loss. Similar technical success was reported by Argyriou *et al.* [11] but with 11% perioperative mortality possibly owing to their more complex open revascularization, that is, femoropopliteal, femorodistal, and cross-over femoral bypass.

The policy not to perform such complex revascularization, in the current study, is to treat the ALI with the simplest way returning the limb either to compensated condition or to normal vascularity. The study working group found this concept logic in such patients and was found achievable using hybrid revascularization with excellent outcome and minimal complications.

A total of 12 (28.8%) of the current study patients had CLTI and were treated by angioplasty of multiple segments through single arterial cutdown, that is, angioplasty alone group. In all of them, tibial angioplasty was done in combination with either proximal SFA angioplasty, iliac intervention, or both. The abandonment of transbrachial and femoral cross-over approaches in these cases was adopted by working surgeons for better wire control and pushability and even luminal passage under vision in proximal SFA.

The main bulk of the patients with CLTI, that, 74 (71.2%) patients, were treated by hybrid intervention using angioplasty to treat inflow segment in 16 (21.6%) patients, outflow segment in 54 (73%), and both in four (5.4%) patients. Dosluoglu *et al.* [21] reported inflow procedures in 85% of their study patients, 5% outflow procedures, and 10% both. This was observed to be nearly the reverse of the current study results, but this can be explained by the more distal distribution of the disease in the Egyptian society as supported by another study on hybrid revascularization by Fareed *et al.* [10]. Another explanation could be the different nature of the lesions treated by angioplasty, as all of them were classified TASC A and B in the current study, whereas Dosluoglu *et al.* [21] treated TASC C and D lesions in more than 48% of their patients.

All technical failure happened in the CLTI category of this study, leading to an overall technical success of 94.8%. When compared with ALI category, this difference could be attributed to the more complex lesions and chronic total occlusions faced in some cases of CLTI rather than acute thrombosis on top of arterial stenosis more amenable to angioplasty.

Regarding the CLTI group of this study, most of the postoperative complications occurred in this group, possibly owing to more complex nature of the disease and the treating procedure. It was observed that hybrid cases had the majority of the postoperative complications than cases offered open access angioplasty only. The working group attributed this to more difficult lesions treated with longer operative time. In addition, the use of prosthetic grafts in the bypass part of the hybrid procedure had its own effect. All cases of early graft occlusion (2.7%) as well as graft infection (4.5%) ended by major amputation. However, late graft occlusion, after 1 year, was managed conservatively and did not affect limb salvage. In addition, all mortality, despite being late and owing to other cardiovascular events, occurred in patients with CLTI. The same observation was found for other types of complications including groin wound complications, leg hematoma, and angioplasty restenosis.

Early 4-month restenosis and outflow occlusion (8.1%) occurred exclusively in patients with a bypass grafts and was treated by balloon dilatation with redo inflow and outflow angioplasty through a contralateral femoral approach with a 100% technical success. This was done for ischemic tissue loss healing during early follow-up. However, restenosis after 6 months (15.7%) and 1 year (11%) was offered conservative treatment and did not affect limb salvage. Moreover, it was not exclusive in bypass patients.The current study reported primary patency of 84.5, 67.6, and 52.7% at 4 months, 6 months, and 1 year, respectively, and secondary patency of 92.7, 76.5, and 62.6% at the same periods. The incidence of reintervention was 8.1% and all were in the first 4 months and were done to assist ischemic lesion healing.

Fareed *et al.* [10] reported a bit higher primary and secondary patency of 78.78 and 100% in 2 years, but they studied hybrid intervention only, unlike our study, and their reintervention rate was higher (21.2%). Similar patency rates were reported in many other studies, but they all studied hybrid techniques only and some of them included claudicant patients [22–24].

Despite the 1-year patency rates of the current study (52.7 and 62.6%), we reported 1-year limb salvage of 91.2%, which sounds logical, as all redo angioplasty was done early in the study as well as all amputations, whereas later occlusions did not affect salvage when occurred, with all lesions healed. Thomas *et al.* [25] reported excellent amputation-free survival of 97%, but 65% of their patients were claudicant, were offered hybrid treatment, and were followed only for 30 days. Similarly, 100% technical success with zero

complications was reported, but they assessed a single hybrid maneuver and 80% of the patients were claudicants.

A unique character of the current study is that we studied all endovascular maneuvers done through an open access with the intent to treat both acute and chronic lower limb ischemia involving hybrid and endoluminal-only revascularization and no claudicant patient was included.

Conclusions

(1) Open access endovascular approaches are easy and feasible techniques that allow application of endovascular therapy in both acute and chronic lower limb ischemia allowing treatment of multilevel disease with different anatomic nature. This is done through hybrid revascularization having the surgical part success augmented by improving inflow and/or outflow by the endoluminal therapy.
(2) The use of open access to perform endovascular therapy alone gives the vascular surgeon the privilege to reach remote and very proximal segments to the access site easily as well as working in opposite directions in the same sessions when needed or preferred by the operator.
(3) In acute ischemia, it gives good revascularization allowing better outcome without performing complex bypass, thus minimizing operative time and complexity.
(4) In the context of chronic ischemia, open endovascular therapy and hybrid technique have acceptable technical success and patency with good limb salvage. However, owing to their complexity and modest patency, these techniques should be reserved to patients with CLTI, keeping conservative measures the cornerstone for treatment of claudicant patients.

Financial support and sponsorship
Nil.

Conflicts of interest
There are no conflicts of interest.

References

1 Adam DJ, Beard JD, Cleavland T, Bell J, Bradbury AW, Forbes JF. Bypass versus angioplasty in severe ischaemia of the leg (BASIL): multicentre randomized controlled trial. Lancet 2005; 366:1925–1934.
2 Huynh TT, Beshara CF. Hybrid interventions in limb salvage. Methodist Debakey CcardiovascJ 2013; IX:90–94.
3 Moneta GL, Yeager RA, Taylor LM Jr, Porter JM. Hemodynamic assessment of combined aortoiliac/femoropopliteal occlusive disease and selection of single or multilevel revascularization. Semin Vasc Surg 1994; 7:3–10.
4 Dalman RL, Taylor LMJr, Moneta GL, Yeager RA, Porter JM. Simultaneous operative repair of multilevel lower extremity occlusive disease. J Vasc Surg 1991; 13:211–219.
5 Harward TR, Ingegno MD, Carlton L, Flynn TC, Seeger JM. Limb-threatening ischemia due to multilevel arterial occlusive disease. Simultaneous or staged inflow/outflow revascularization. Ann Surg 1995; 221:498–503.
6 Dougherty MJ, Young LP, Calligaro KD. One hundred twentyfive concomitant endovascular and open procedures for lower extremity arterial disease. J Vasc Surg 2003; 37:316–322.
7 Marin ML, Veith FJ, Cynamon J, Sanchez LA, Wengerter KR, Schwartz ML, *et al.* Transfemoral endovascular stented graft treatment of aorto-iliac and femoropopliteal occlusive disease for limb salvage. Am J Surg 1994; 168:156–162.
8 Parodi JC. Endovascular repair of abdominal aortic aneurysms and other arterial lesions. J Vasc Surg 1995; 21:549–555.
9 Norgren L, Hiatt WR, Dormandy JA, Nehler MR, Harris KA, Fowkes FGR, *et al.* Inter-society consensus for the management of peripheral arterial disease (TASC II). J Vasc Surg 2007; 45(Suppl S):S5–S67.
10 Fareed A, Zaid N, Alkhateep Y. Hybrid revascularization techniques in the treatment of multiple level peripheral vascular disease. Egypt J Surg 2018; 37:96–103.
11 Argyriou C, Georgakarakos E, Georgiadis GS, George, Antoniou A, Schoretsanitis N, Lazarides M. Hybrid revascularization procedures in acute limb ischaemia. Am Vasc Surg 2014; 28:1456–1462.
12 Shiraki T, Iida O, Suemitsu K, Tsuji Y, Uematsu M. Retrograde approach using surgical cutdown technique for limb salvage in a case of critical limb ischemia with severely calcified tibial occlusive disease. Vasc Endovasc Surg 2016; 50:295–298.
13 Liang G, Zhang F, Luo X, Zhang C, Feng Y, Niu L, *et al.* Routine use of surgical retrograde transtibial endovascular approach for failed attempts at antegrade recanalization of chronic peripheral artery total occlusions. Cardiovasc Intervent Radiol 2016; 39:1692–1701.
14 Coughlin P. Epidemiological risk factors for PAD, risk stratification and risk factor management. In: Loftus L, Hinchliffe RJ, editors. Acompanion to specialist surgical practice: vascular and endovascular surgery. 6th Ed. Amsterdam: Elsevier; 2019; 1:1–12.
15 Al-Delaimy WK, Merchant AT, Rimm EB, Willett WC. Effect of type 2 diabetes and its duration on the risk of peripheral arterial disease among men. Am J Med 2004; 116:236–240.
16 Diehm N, Shang A, Silvestro A, Do DD, Dick F, Schmidli J. Association of cardiovascular risk factors with pattern of lower limb atherosclerosis in 2659 patients undergoing angioplasty. Eur J Vasc Endovasc Surg 2006; 31:59–63.
17 Haltmayer M, Mueller T, Horvath W, Luft C, Poelz W, Haidinger D. Impact of atherosclerotic risk factors on the anatomical distribution of peripheral arterial disease. Int Angiol 2001; 20:200–207.
18 Vogt MT, Wolfson SK, Kuller LH. Segmental arterial disease in the lower extremities: correlates of disease and relationship to mortality. J Clin Epidemiol 1993; 46:1267–1276.
19 Aboyans V, Desormais I, Lacroix P, Salazar J, Criqui MH, Laskar M. The general prognosis of patients with peripheral arterial disease differs according to the disease localization. J Am Coll Cardiol 2010; 55:898–903.
20 Chen Q, Shi Y, Wang YT, Li X. Patterns of disease distribution of lower extremity peripheral arterial disease. Angiology 2015; 66:211–218.
21 Dosluoglu HH, Lall P, Cherr GS, Harris LM, Dryjski ML. Role of simple and complex hybrid revascularization procedures for symptomatic lower extremity occlusive disease. J Vasc Surg 2010; 51:1425–1435.
22 Cotroneo R, Lezzi G, Marano B, Fonio F, Nessi G, Gandini G. Hybrid therapy in patients with complex peripheral multifocal steno-obstructive vascular disease: two-year results. Cardiovasc Intervent Radiol 2007; 30:355–361.
23 Nishibe T, Kondo Y, Dardik A, *et al.* Hybrid surgical and endovascular therapy in multifocal peripheral TASC D lesions: up to three-year follow-up. J Cardiovasc Surg (Torino) 2009; 50:493–499.
24 Schrijver AM, Moll FL, De Vries JP. Hybrid procedures for peripheral obstructive disease. J Cardiovasc Surg (Torino) 2010; 51:833–843.
25 Thomas H, Aly M, Wong MT, Moffat D, Mackenzie S, Choksy S, Moffat D. Hybrid surgical and radiological revascularization for diabetic and non-diabetic lower limb ischaemia. J Curr Surg 2012; 2:119–122.