Safety and efficacy of infraclavicular arterioarterial chest wall prosthetic loop graft for hemodialysis access: a review of 45 patients

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Introduction
With raising the demand for hemodialysis (HD) owing to concomitant increased incidence of nephropathic disease, which has led to associated increased patients' life expectancy in the past three decades, it becomes necessary to establish a secondary or a tertiary HD vascular access to overcome the exhausted peripheral veins and central venous occlusion.

Aims
Our case study reports midterm (24-month follow-up) results with infraclavicular arterioarterial loop graft and evaluates its efficacy and safety in construction of HD vascular access for patients with end-stage renal disease.

Material and methods
This was a prospective study. From December 2014 to December 2017, 45 patients with end-stage renal disease on chronic HD with exhausted all peripheral and central veins or were considered unsuitable for creation of arteriovenous fistula/graft owing to heart failure underwent arterioarterial chest wall prosthetic graft implantation for creation of HD vascular access. The data analysis was done using SPSS version 20.0 for Windows.

Results
The primary patency rates were 100, 97.7, 93, 77.5, and 73.7% at 6, 9, 12, 18, and 24 months, respectively. The secondary patency rates were 100, 85.7, and 66.6% at 6, 9, and 12 months, respectively, after successful thrombectomy in nine patients. There were 20 (44.4%) secondary variable procedures performed in 18 (40%) patients during follow-up period, with no procedure-related mortality or limb-threatening conditions being documented in our study.

Conclusion
Our case study reports a reasonable midterm patency rate, and complications associated with this pattern of vascular access show that infraclavicular arterioarterial loop grafts are a valid alternative option for complex patients. We advocate the use of this technique in patients with exhausted all vascular access possibilities in both upper extremities with central venous obstruction. We also indicate it in case of patients with cardiac insufficiency who could not tolerate long-term hemodynamic effect of arteriovenous fistula/graft.

Keywords:
arterioarterial, cardiac insufficiency, central venous occlusion, hemodialysis, vascular access

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Introduction

Vascular access has been regarded as a lifeline for patients with end-stage renal disease on regular dialysis. Autogenous arteriovenous fistula (AVF) is the golden standard and the angioaccess of choice for hemodialysis (HD); however, it has always been the Achilles' heel for HD [1]. According to Kidney Disease Outcomes Quality Initiative guidelines, all available autogenous AVF should be utilized and exhausted before resorting to central venous catheter (CVC) as an alternative dialysis access [2]. The increase of patients' life expectancy, with the limited durability of these angioaccesses, increases the demand to repeat fistula construction at different upper extremity levels (wrist, forearm, and upper arm) and can ultimately result in exhaustion of autogenous AVF [3]. Moreover, in some patients with central venous obstruction owing to stenosis or occlusion, CVC cannot be established for HD, unless endovascular and surgical intervention is carried out to restore venous patency [4]. Patients whose vascular access is exhausted and demands more complicated access procedures, a synthetic arteriovenous loop graft utilizing the axillary artery and vein in those patients has been reported as a good alternative approach for

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HD [5–7]. However, in patients with occluded central veins, arteriovenous loop grafts are not applicable. In these patients, an arterioarterial prosthetic loop or straight graft pattern can be the only option for a reliable alternative HD access [8].

Materials and methods

We conducted an analysis of prospectively collected data over a 3-year period in between December 2014 and December 2017 for 45 patients (32 men and 13 women) with end-stage renal disease who underwent infraclavicular arterioarterial chest wall prosthetic graft procedures as a permanent vascular access for HD. After the local hospital's ethical and scientific committee approved the study protocol, patients were enrolled at Vascular Surgery Unit, Benha University; Department of Surgery, Vascular Surgery Department; Nile Insurance Hospital, and Vascular Surgery Department; Helwan University. An infraclavicular arterioarterial loop graft (IAALG) procedure was indicated only for patients who had no suitable superficial cephalic and basilic veins for an AVF and who belonged to one of the following indication:

(1) Cardiac insufficiency that was refractory to medical therapy confirmed by echocardiography-based ejection fraction less than or equal to 40%. Those patients were intolerable to the additional cardiac load of a high-flow AVF/arteriovenous graft (AVG) with the risk of exacerbation of congestive heart failure.
(2) The unsuitability of large six deep veins (the subclavian, internal jugular, and femoral veins). A vein was considered unsuitable when an occlusion or high-grade long stenosis (<70% in diameter, >4 cm long) of the venous outflow that was confirmed by computed tomography venography and lesion treatment by percutaneous interventions was demanding.
(3) Patients with at least one patent central vein that should be preserved as bailout access for an emergency CVC.

The rationale of arterioarterial loop graft is based on lengthening an artery using expanded polytetrafluoroethylene (PTFE) graft in loop configuration [9]. In our study, we used the subclavian (third part) and axillary artery (second part) as the inflow and outflow vessels in all studied patients. Patients' characteristics are shown in Table 1. All procedures were done under local anesthesia with supraclavicular nerve block, except in 12 (26.7%) patients who required general anesthesia owing to their BMI being greater than 30, which made dissection under

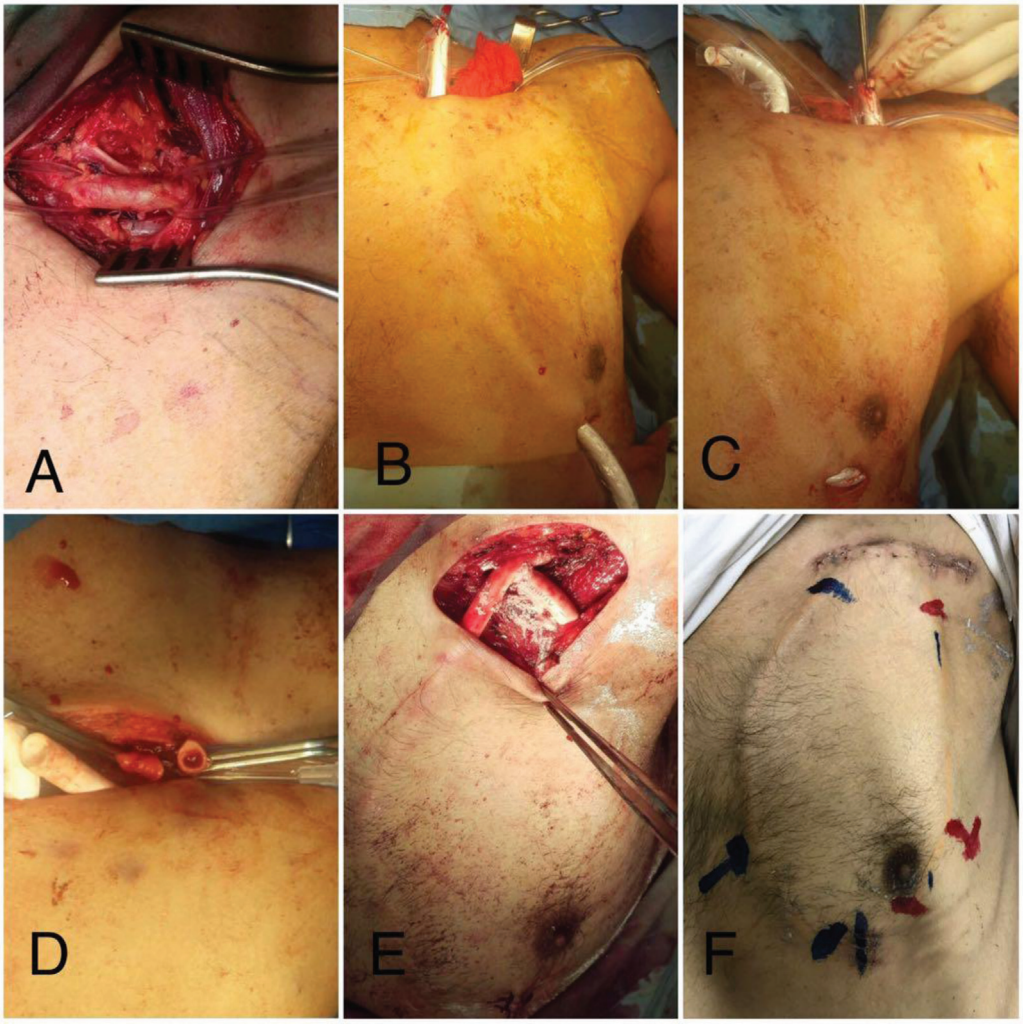
Table 1 Demographic data, medical history, and results of the studied patients

Study group	*n* (%)
Sex	
Male	32 (71.1)
Female	13 (28.9)
Age (years)	
Range	28–56
Mean±SD	44.76 ±7.83
Coronary artery disease	23 (51.1)
Diabetes mellitus	21 (46.7)
Hypertension	29 (64.4)
Hyperlipidemia	14 (31.1)
Documented hypercoagulability	6 (13.3)
BMI >30	12 (26.7)
Positive hepatitis markers	15 (33.3)
Clinical indications	
Heart failure	19 (42.2)
Unsuitable deep central veins	11 (24.4)
Combined exhausted accesses and unsuitable deep central vein	13 (28.9)
Steal syndrome with digital gangrene	2 (4.4)
Patients with previous procedures	26 (57.8)
Previous procedures	
range for every patient	4.0–12.0
Mean±SD	7.67±2.26
Primary graft patency	
6 months	43/43 (100)
9 months	42/43 (97.7)
12 months	40/43 (93)
18 months	31/40 (77.5)
24 months	28/38 (73.7)
Secondary graft patency	
6 months	9/9 (100)
9 months	6/7 (85.7)
12 months	2/3 (66.6)
Required secondary procedures	
Graft removal	7 (15.6)
Surgical graft thrombectomy	9 (20)
Resection of graft aneurysm with interposition graft repair	3 (6.7)
Transverse severance of outflow limb and bypass graft from loop graft to brachial artery	1 (2.2)
Complications	
Graft infection	3 (6.7)
Early	1 (2.2)
Late	2 (4.4)
Anastomotic pseudoaneurysm	1 (2.2)
Graft thrombosis	11 (24.4)
Graft rethrombosis	2/9 (22.2)
Puncture site pseudoaneurysm	7 (15.6)
Outflow anastomotic site stenosis	2 (4.4)

local anesthesia painful and difficult. The incision was made about three-finger breadth below the middle one-third of clavicle and is 8–10 cm long. The pectoralis major muscle was splitted along the direction of its fibers, and the pectoralis minor muscle was divided. The subclavian/axillary vein was now exposed. Ligation of tributaries to the vein, particularly those crossing in front of the artery, was mandatory for adequate mobilization. Approximately 5–6 cm of the subclavian/axillary artery should be mobilized (Fig. 1a). A circular subcutaneous tunnel was then made on the previously marked chest wall (Fig. 2a) in which the graft was placed in loop configuration with assistance of small counter incision (Figs 1b,c and 2c). Following clamping of the subclavian/axillary artery after systemic heparinization, transverse severance of the artery was done (Fig. 1d). An end-to-end anastomosis was made between the proximal arterial segment and a PTFE prosthesis having a diameter of at least 7 mm, and an end-to-end anastomosis with the distal arterial was performed using 6-0 prolene (Figs 1e and 2b).

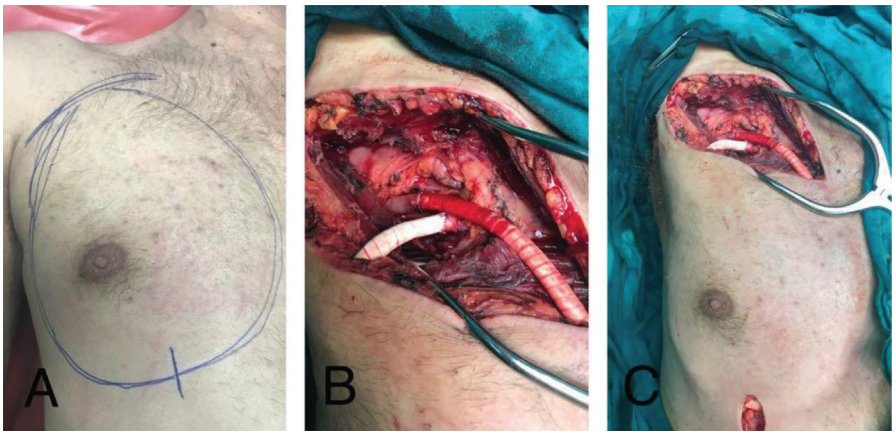
The grafts used in our study were the 7-mm Flixene (Atrium Medical, Hudson, New Hampshire, USA) in 33 patients and the 7-mm FlowLine Bipore (JOTEC GmbH, Lotzenäcker, Germany) in 12 patients. In the immediate postoperative period, small to moderate hematoma occurred in the tunnel caused by the chest wall collateral venous circulation and aggravated by anticoagulants. Central venous inadequacy were confirmed in all patients by computed tomography venography. Color duplex ultrasound scanning of arteries was regarded as mandatory for all patients. An arteriography was indicated in all cases of suspected arterial inflow or outflow lesions. After the perioperative administration of heparin, patients with heart failure or hypercoagulability received oral anticoagulation (warfarin), with an international normalized ratio of 2.5–3.0. Other patients received aspirin only (150 mg/day). Patients were discharged on the second postoperative day. The first needle puncture of the graft was done not before 2 weeks after the procedure

Fig. 1



(a) Exposure of axillary artery; (b) tunneling of the graft; (c) chest wall loop configuration graft; (d) transection of axillary artery for anastomosis; (e) interposition omega loop graft; and (f) 2 weeks after procedure.

Fig. 2



(a) Preoperative skin mapping; (b) end-to-end anastomosis; and (c) interposition omega loop graft.

except for patients with flixene graft implants, where puncture was allowed on fifth postoperative day after hematoma and inflammatory process subsided (Fig. 1f). Patients were advised to compress the puncture site for 20 min after the removal of the needle and to avoid any infusion of medications through the graft during dialysis (intra-arterial injection). We followed up our patients at an outpatient clinic at regular monthly visits. Duplex assessments were carried out every 6 months to assess patency or when clinically indicated.

Results

In our case series study, 45 patients underwent infraclavicular arterioarterial chest wall prosthetic graft procedure from December 2014 to December 2015 with 24 months of follow-up from the last patient operated upon. Of them, 13 (28.9%) were female and 32 (71.1%) were male patients. The demographic data are presented in Table 1. Age ranged between 28 and 56 years with the mean of 44.76±7.83 years. Twenty-three (51.1%) patients had coronary artery disease, 19 (42.2%) patients had heart failure, diabetes mellitus was present in 31 (46.7%) patients, hyperlipidemia in 14 (31.1%) patients, and documented hypercoagulability in six (13.3%) patients. Twelve (26.7%) patients had BMI greater than 30. Of our patients, 26 (57.8%) patients underwent previous dialysis access procedures ranged between 4 and 12 procedures for each patient with the mean of 7.67±2.26. The patients' clinical characteristics were as follows: 11 (24.4%) patients had no suitable upper body veins and suitable femoral veins, and five (11.1%) of them had superior vena cava occlusion. Nineteen (42.2%) patients had a moderate congestive heart failure (New York Heart Association class III, ejection fraction <40%), and it was regarded as an indication for arterioarterial grafts. Thirteen (28.9%) patients had combined unsuitable central veins and exhausted upper limb dialysis access. Two (4.4%) patients had suitable central veins, but they all had a severe steal syndrome, with finger necrosis at a low-flow native AVF. The necrosis healed after the construction of the chest wall IAALG and the ligation of the AV access. All constructed grafts remained functioning for first 6 months (100%). Eighteen (40%) patients required 20 (44.4%) secondary procedures owing to complications. The most common complication was graft thrombosis; it occurred in 11 (24.4%) patients. Surgical thrombectomy was done in nine (20%) patients. The other two thrombosed grafts were secondary to late graft infection that necessitated grafts removal. Puncture site aneurysm occurred in seven (15.6%; Fig. 3) cases, where surgical repair by aneurysm resection and interposition of graft through healthy subcutaneous route was done in three (6.7%) of them; in the other four patients, we decided to remove

Fig. 3

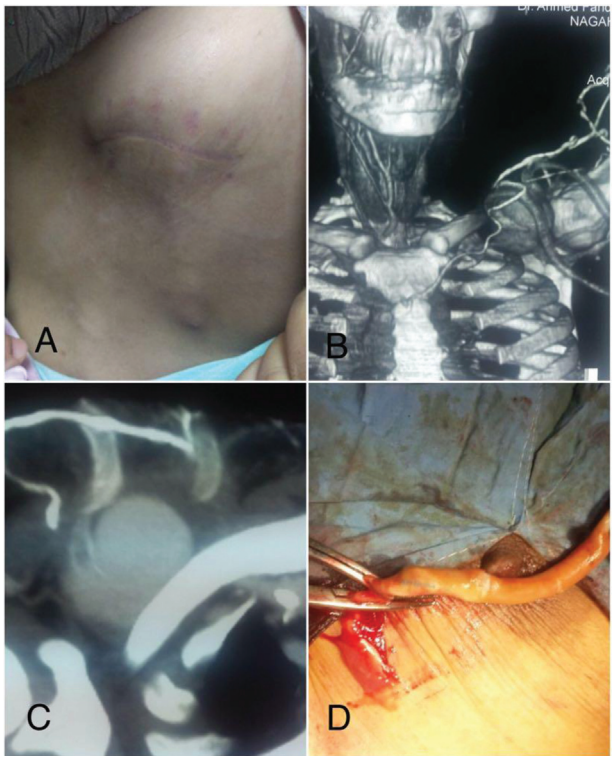
Puncture site pseudoaneurysm 16 months after procedure.

the grafts owing to large size with ulcerated overlying skin. Graft infection rate was 6.7%; one infected graft presented with anastomotic pseudoaneurysm 2 weeks after operation (Fig. 4). Anastomotic stenosis of the distal graft limb occurred in two (4.4%) patients, and one (2.2%) patient was treated surgically by transverse severance of the distal limb, securing the distal stump and bypassing the graft to proximal brachial artery (Fig. 5c). The primary graft patency was 100, 97.7, 93, 77.5, and 73.7% at 6, 9, 12, 18, and 24 months, respectively, and the secondary patency was 100, 85.7, and 66.6% at 6, 9, and 12 months (Fig. 6). There was no mortality within 30 days of follow-up. Our study showed that IAALG did not aggravate congestive heart failure in patients with cardiac insufficiency during the 2-year follow-up; all patients were New York Heart Association class III with no significant changes in ejection fraction. There were no embolic complications in our studied group. No upper extremities-threatening ischemia was observed in the seven (15.6%) patients who underwent surgical graft removal with ligation of inflow and outflow artery other than cold extremities.

Discussion

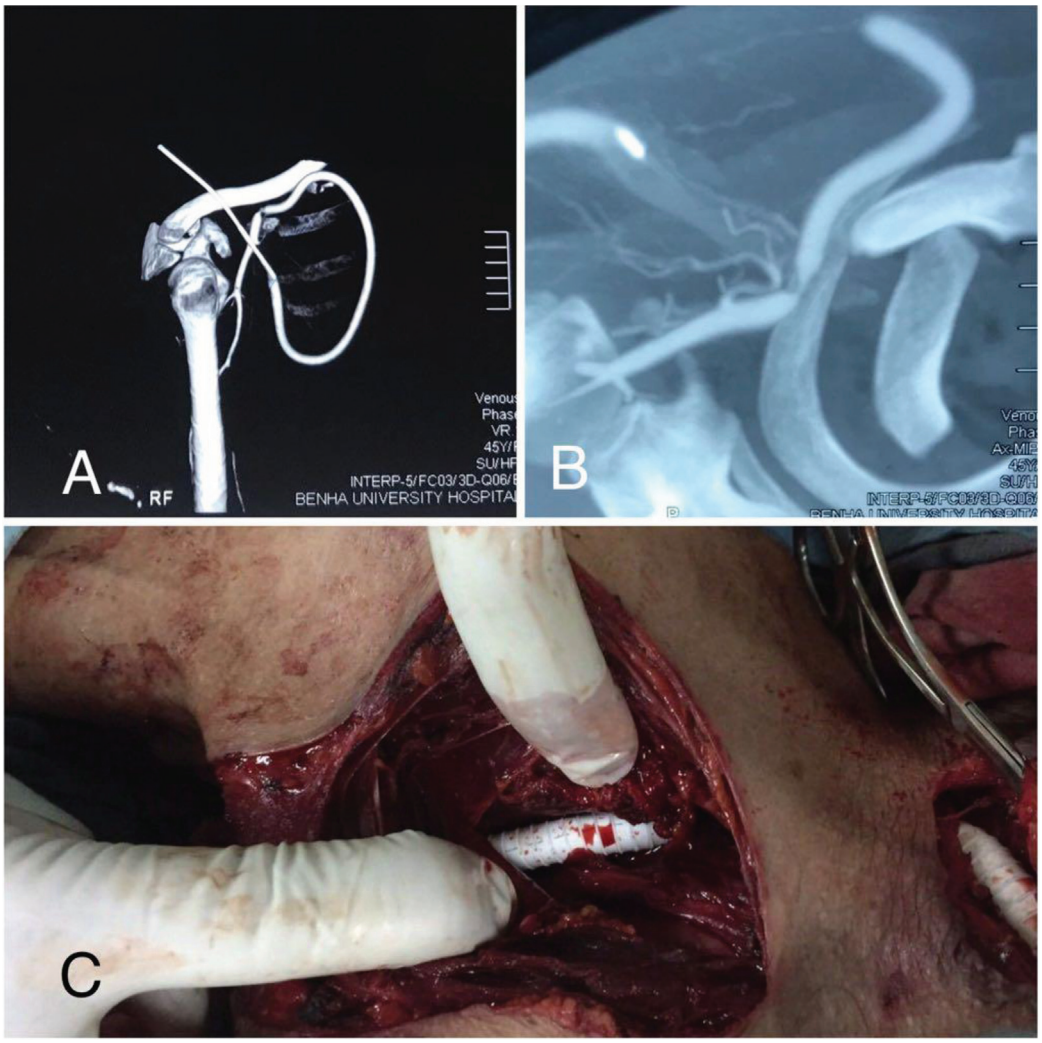
Utilizing different arterial segments all over the body as the inflow and outflow-based dialysis access in the form of interposition loop graft or jumping bypass is not recently known. Brittinger *et al.* [10] used subcutaneously transposed superficial femoral artery for HD in a series of 17 patients. It was criticized owing its traumatic effect on the artery causing stenosis, thrombosis, and aneurysmal dilatation caused by recurrent arterial cannulation. Zingraff *et al.* [11] performed a femoropopliteal bypass using a carotid bovine graft that developed thrombosis of the superficial femoral artery in a young girl on HD. In our current study, we indicated IAALG for HD as bailout option in those patients who cannot tolerate the hyperdynamic effect of high-flow AVF/AVG owing to cardiac insufficiency or had exhausted conventional arteriovenous vascular access. It is an exotic access strategy that should not be compared with autogenous AVF or conventional AVG, but if we do, it should be against femoral loop graft or hemodialysis reliable outflow (HeRO). Regarding recent endovascular therapy to regain central venous patency by balloon angioplasty with or without stenting or by other newer technique like HeRO device that depends on the ability to pass the guidewire through the totally occluded centeral veins allowing permanent metal catheter reaching a right atrium, are still controversial and associated with high costs in relation to its durability, so renew utilization of arterial-based dialysis access is getting worth in those patients. In our study, we performed 45 IAALG procedures that represented subcutaneous placement of interposition loop graft through a tunnel in anterior chest wall owing to previous indications. We encountered the usual complications of any prostheses, including infection 6.7%, pseudoaneurysm 17.8% (anastomotic and puncture site) and thrombosis 24.4%, which required 20 secondary variable procedures. The primary patency rates were 100, 97.7, 93, 77.5, and 73.7% at 6, 9, 12, 18, and 24 months, respectively. The secondary patency was 100, 85.7, and 66.6% at 6, 9, and 12 months, respectively, after successful thrombectomy. Regarding secondary patency at 9 and 12 month is lower than primary patency, this may be due to underlying culprit anastomotic intimal hyperplasia that was not routinely angiographically assessed intraoperatively during thrombectomy procedures or that developed later on top of graftotomy incision. These results are comparable to Lei *et al.* [12]; however, they utilized common femoral and deep femoral arteries. Lei *et al.* [12] reported primary and secondary patency rates in 18 patients operated upon for thigh arterioarterial loop graft of 94.5 and 88.8%, respectively, at 6 months; these rates at 3 years were 61 and 72%, respectively. Khafagy *et al.* [13] reported primary patency rates of 87.9, 70.4,

Fig. 4



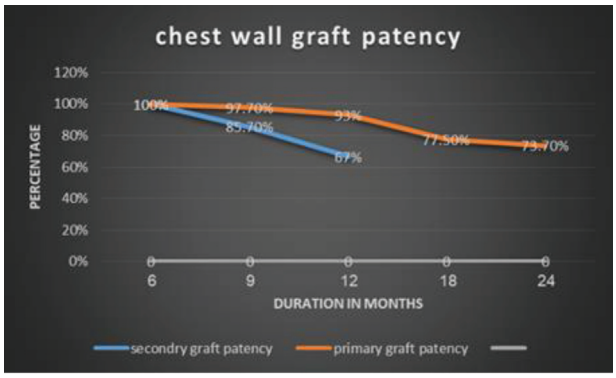
(a) Anastomotic pseudoaneurysm 1 month after procedure; (b and c) computed tomography angiography (CTA) confirming the diagnosis; and (d) explanted infected graft with ligation of axillary artery.

Fig. 5



(a and b) computed tomography angiography (CTA) of outflow limb anastomotic significant stenosis; and (C) bypass graft from the outflow limb to proximal brachial artery.

Fig. 6



Primary and secondary graft patency.

and 38.8% at 12, 24, and 36 months, respectively. The secondary patency rates were 90.7, 80.3, and 67.6% at 12, 24, and 36 months, respectively, in 35 brachial arterioarterial prosthetic loops [13]. We observed that thrombosis of axillary loop graft was well tolerated, and in the cases of an abandoned infraclavicular arterioarterial axillary loop graft, the arterial reconstruction was not mandatory because of good collateralization and no patients' symptoms except cold extremities. In contrast to femoral–deep femoral artery loop graft, thrombosis might require immediate thrombectomy; however, if the whole graft becomes infected, it is mandatory to remove the graft and reconstruct the artery [14]. Owing to the intraluminal arterial pressure of the arterioarterial grafts, that is much higher than the pressure of a well-working AVG, the risk of developing puncture sites false aneurysm is increased. Regarding puncture site pseudoaneurysm, we reported seven (15.6%) patients who developed pseudoaneurysm; three (6.7%) of them were treated with resection and interposition graft. This is comparable to the rate reported by Khafagy *et al* [13]. Regarding the efficacy of our procedures during the follow-up period, all patients except the two who developed

outflow stenosis had effective dialysis, proved clinically by no additional dialysis sessions required or prolonged sessions and through laboratory by creatinine clearance. The infraclavicular arterioarterial axillary loop graft was preferred to femoral arterioarterial prosthetic graft, even though an equivalent patency was reported. This preference is based on a tolerable malperfusion, mostly without any signs of limb-threatening ischemia, in the case of thrombosis of IAALG. The much more comfort for the patients and the associated lower risk of infection are additional arguments in favor of IAALG [15]. The IAALG has to be dealt with as an artery, and avoiding intra-arterial medication infusion and careful digital compression of the puncture sites after needles removal with frequent change of the puncture sites must be considered.

Conclusion

In our study, we renew the concept of arterial-based angioaccess for HD as a reliable bailout alternative for HD access in patients who are not candidates for conventional HD vascular access. The results of our study highlight the potential benefit of arterioarterial grafts that may be supported by use of new generation of three-layer PTFE synthetic graft. The limited available data and long-term results about the procedure should call for more studies to evaluate this treatment strategy as an alternative option when all AVF/AVG options are exhausted.

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Conflicts of interest

There are no conflicts of interest.

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