Partial excision of brachial arterio-venous fistula body and venous limb to treat steal syndrome in haemodialysis patients

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Background
Steal syndrome is one of the complications of dialysis arterio-venous fistula (AVF) characterized by decrease digital arterial pressure from preferential blood flow through the low pressure venous outflow. It has clinical importance when leading to hand ischaemia, heart overload, or both. High flow steal has the distal upper limb arteries intact. Treatment options include ligation, change fistula inflow, and banding procedures. Partial fistula excision and reclosure is a technique that tries to limit the AVF hyperfunction to improve hand ischaemia.

Aim of the work
To assess feasibility, outcome, and complications of partial shunt excision to treat hyperfunctioning steal.

Patients and methods
The study included 20 patients, 12 women and 8 men, with high flow steal hand ischaemia from September 2018 to December 2020. Preoperative duplex assessment of fistula outflow volume and wrist arteries was performed. All patients had partial fistula body and outflow excision, resizing, and suture closure in 3-month follow-up for clinical and duplex outcome.

Results
Significant decrease of fistula outflow volume after the procedure from 1847.50±656.04 to 1258.50±413.93 and increase in wrist arterial peak systolic velocity from 23.50±8.64 to 56.80±15.03 (P=0.002 and P<0.002), respectively, were found. Complete relief of hand ischaemic symptoms in 75% of patients, partial improvement in 25% with minimal postoperative complications, no reintervention, and no limb loss during follow-up with 3-month 100% patency was noted.

Conclusion
Partial shunt excision is a feasible flow limiting procedure that can treat high flow AVF effectively with minimal complication.

Keywords:
arterio-venous fistula, haemodialysis, steal syndrome

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Introduction

Arterio-venous fistula (AVF) was considered the ideal circulation access for haemodialysis since the observation of James Cimino that traumatic AVFs in war injuries had no significant health consequences [1]. However, for a functioning dialysis AVF, several types of complications are reported including infection, thrombosis, stenosis, aneurysm formation, ischaemic neuropathy, heart failure, and steal syndrome [2].

AVF has tendency to decrease digital arterial pressure due to preferential blood flow through the low resistance. This happens in all fistulae as a usual haemodynamic change secondary to arterial shunting to venous circulation [3]. Such changes may or may not produce significant ischaemic hand symptoms. The reduction in digital perfusion is augmented when additional arterial stenosis is present producing the so called low flow steal [4], which can be managed either by endovascular balloon dilatation of the arterial stenosis, or even by shunt ligation when endovascular therapy is not feasible or fails.

A high flow steal produced by a significantly hyperfunctioning fistulae is an uncommon access complication. However, they have serious sequelae presenting clinically with heart failure, steal syndrome, or both [5].

Steal syndrome has different degrees ranging from pallor and cyanosis up to hand ischaemic ulcer and gangrene [6]. However, a distinguishing character to diagnose steal is the disappearance of pain when venous limb is compressed or at the end of the dialysis session [5].

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Proximal AVF, old age, diabetes mellitus (DM), cardiac dysfunction, and peripheral arterial disease are known predisposing factors to clinically significant steal [7].

Significant steal manifestations presented with rest pain and/or ischaemic tissue loss are only present in 1–8% of patients with upper limb haemodialysis access [6]. However, mild steal manifestations are more common that, at least, single symptom is present in 80% of arm fistulae, 50% of forearm loops, and in 40% of wrist AVFs most of them are mild and can be treated conservatively [8].

Correlating the fistula site with symptomatic steal, ischaemic symptoms were found in 10–25% of brachial procedures (in grafts more than native fistulae), 4–6% of forearm loops, and in 1–2% of wrist fistulae [9].

Serious manifestations of steal syndrome, despite being rare (1–8%), carry a risk of limb or fingers loss and heart failure as well, thus require correction. Moreover, ischaemic neuropathy can be augmented or even turns irreversible if steal is not corrected [6].

Treatment of such cases carries some difficulties and risks including operative risk in such potentially high-risk patients and the possibility of limb loss. Hence, preventive measures taken to guard against occurrence of steal are important including preoperative evaluation and technical points during fistula creation [2].

Many procedures are adopted to treat significant steal syndrome. The most effective one is venous limb ligation but this includes loss of the vascular access in addition to the correction of hand ischaemia. Other procedures include operations that redirect fistula inflow and flow limiting procedures. Redirecting fistula inflow include proximalization of arterial inflow (PAI), revascularization using distal inflow (RUDI), and distal revascularization interval ligation (DRIL) for proximal fistulae and distal radial artery ligation for wrist fistula with reversal of radial arterial flow through the palmar arches [10,11].

Many procedures are described to limit the flow of a hyperfunctioning fistula including banding, prosthetic graft interposition as part of the venous limb, T-banding of the fistula body and venous outflow, arterial stoma narrowing, and fistula plication [12–14].

In this study, we described a technique of partial fistula excision and reclosure to limit the AVF hyperfunction aiming to improve distal arterial flow of the upper limb affected with keeping the fistula functioning in a trial to offer the patients a durable solution of such problem.

Aim of the work

The aim of this study was to describe and evaluate the details of a flow limiting technique in treating hyperfunctioning dialysis AVF causing steal. The study, also, assessed feasibility of the technique, short-term efficacy, and complications.

Patients

This study included 20 patients admitted to the Vascular Surgery Unit, Department of Surgery, Faculty of Medicine, Alexandria University and Department of Experimental and Clinical Surgery, Medical Research Institute, Alexandria University from September 2018 to December 2020. After approval of the Ethical Committee of the Faculty of Medicine, Alexandria University, an informed consent was taken from every patient. The study was done according to The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Inclusion criteria

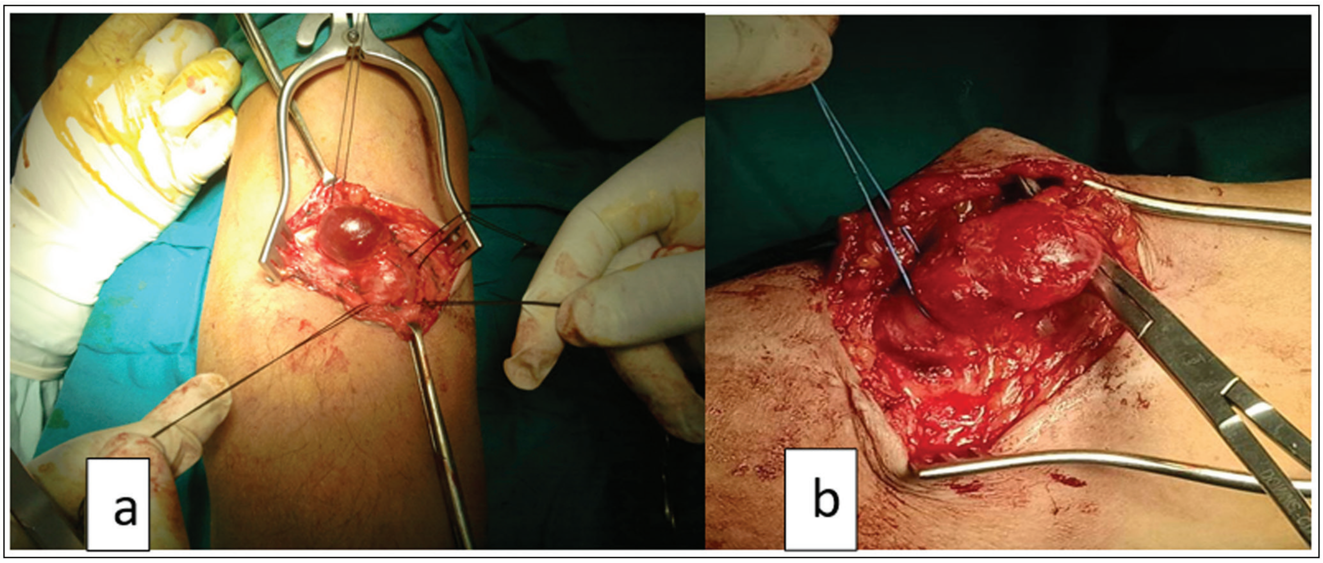
Patients with brachial AVF (either brachiocephalic or brachiobasilic AVF) for dialysis for end-stage renal disease (ESRD) having:

(1) Ischaemic symptoms, for example, coldness, numbness, ischaemic pain either at rest or during dialysis.
(2) Ischaemic signs: cold hand, cyanosis, ischaemic ulceration, digital gangrene, lost wrist pulses.
(3) Clinical test: regained pulse after digital fistula compression denoting intact forearm arteries.
(4) Duplex evidence of hyperfunctioning AVF by high flow in the fistula venous outflow and decreased wrist arterial flow with or without reversal that improves with fistula compression.

Exclusion criteria

(1) Patients with distal arterial occlusive disease of the upper limb affecting radial and/or ulnar artery detected by:
    (a) Negative clinical test, that is, no regained wrist pulses on fistula outflow compression.
    (b) Duplex evidence of radial and ulnar artery occlusive disease.
    (c) No flow improvement of wrist arterial flow on fistula compression denoting that this steal was not due to fistula hyperfunction or a combination of hyperfunction and distal upper limb arterial disease was present.
(2) Patients who had synthetic shunt grafts.
(3) Patients having major gangrene of the upper limb indicating amputation.
(4) Congestive heart failure.

Figure 1



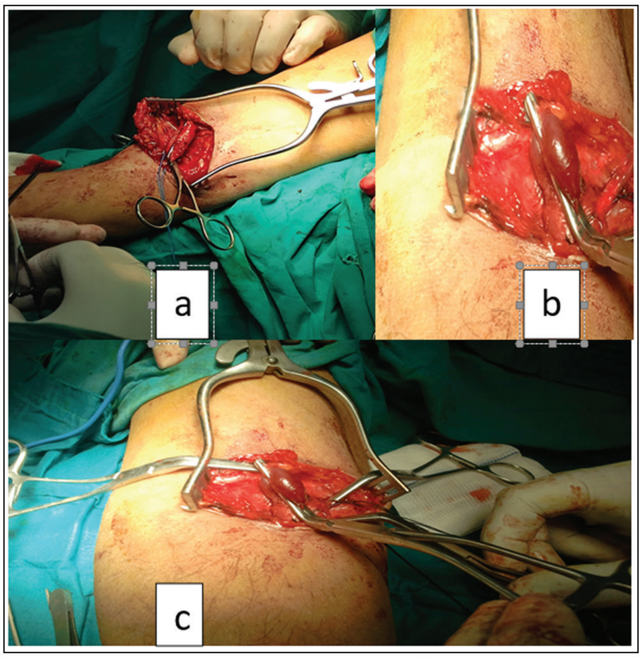
(a) Four limbs exposure of brachiocephalic fistula. (b) Fistula body and venous outflow exposure.

Methods

All patients of the study were subjected to:

(1) History taking.
(2) Thorough clinical examination.
(3) Lab investigations.
(4) Complaining upper limb duplex ultrasound:
  (a) To measure flow volume (FV) (ml/min) through the fistula and its venous outflow limb.
  (b) Determine patency of distal arm vessels for exclusion of distal arterial disease.
  (c) To measure the distal arterial radial and ulnar artery peak systolic velocity (PSV) (cm/s). Recording the maximum wrist PSV.
(5) Full informed consents were obtained from all study patients before the procedure.
(6) Technique:
  (i) Under general or regional interscalene nerve block, the patient was placed in supine position, exposing the target fistula through an antecubital skin incision to dissect fistula body and arterial and venous limbs. The venous and arterial limbs were exposed in a way that allows control of the proximal arterial, distal arterial, and venous limbs separately as in Fig. 1a, or in a way that allows control of the venous outflow from one side and the whole fistula body from the other (Fig. 1b).
(7) An atraumatic vascular clamp (angled DeBakey clamp) was applied, in a side biting way, to the anterior wall of part of fistula body and its adjacent venous outflow limb. This was done in a way partially occluding the fistula trying different levels until reaching a partial occlusion level with which a wrist pulse was regained together with functioning fistula, that is, thrilling fistula with regained wrist pulse. This level of partial occlusion would determine the optimal resizing of the fistula outflow that abolished steal and preserved shunt function (Fig. 2a,b).

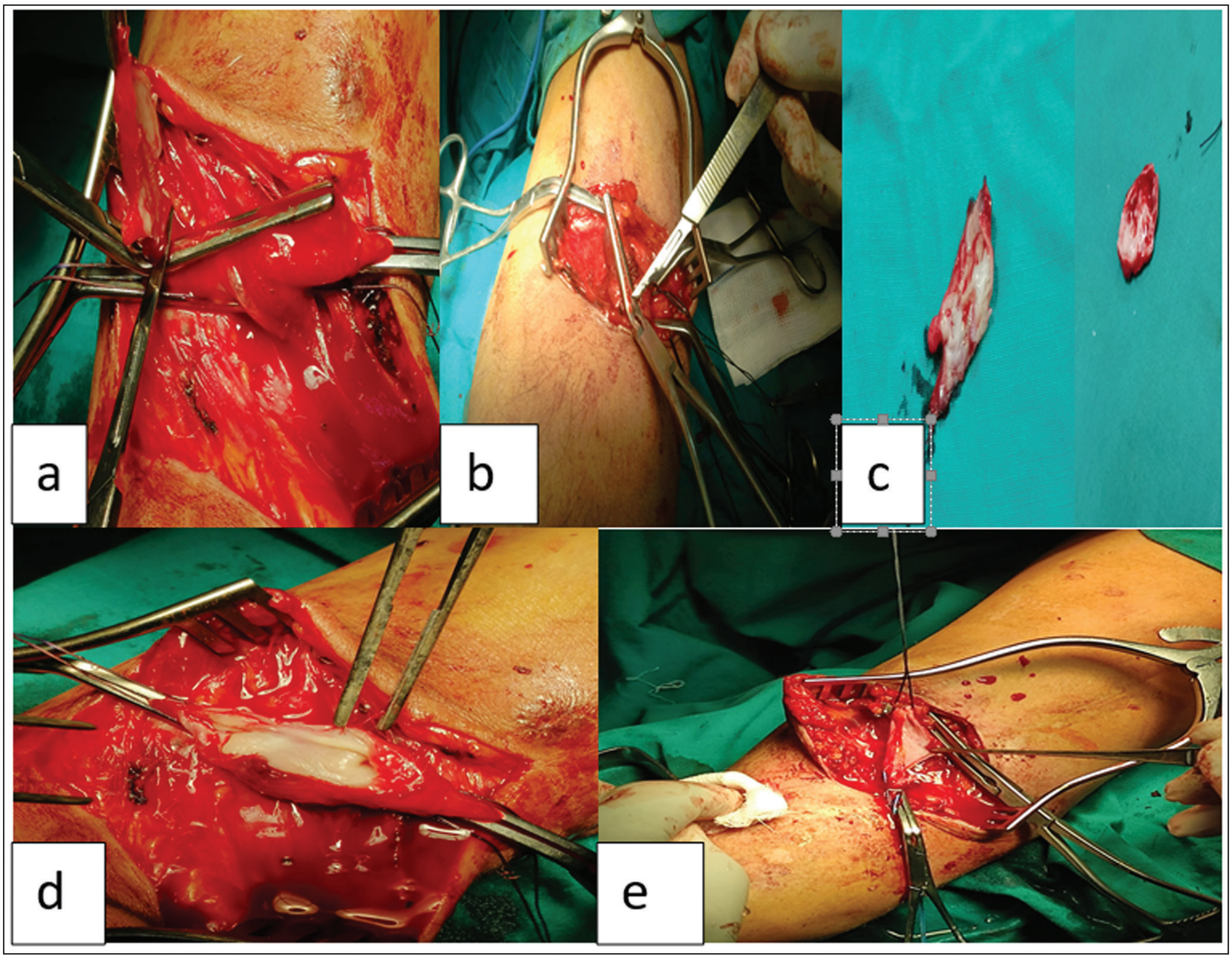
Figure 2



(a, b) Fistula outflow resizing. (c) Control clamping after resizing.

(8) Control of the fistula limbs using atraumatic vascular clamps (Fig. 2c).
(9) Removal of an ellipse of the fistula body, and its venous outflow limb defined by the side-biting resizing clamp (Fig. 3a–e).

Figure 3



Fistula body and venous outflow partial excision. (a, b) Excision of the fistula part determined by the clamp. (c) Excised portion of the wall. (d, e) Resized fistula before closure.

(10) Closure of the fistula body and outflow limb using continuous polypropylene sutures (Fig. 4).
(11) Suction drainage and wound closure.
(12) Follow-up: studied patients were followed for 3 months postoperatively as regards:
- Dialysis access function.
- Relief of ischaemic manifestations of the upper limb.
- Duplex scanning immediately after stiches removal and before fistula use in dialysis to measure FV of fistula outflow (ml/min) as well as the maximum wrist arterial PSV (cm/s) to detect change from the preoperative values.
- Procedure complications in the form of fistula occlusion, infection, hemorrhage, recurrent steal, and reperfusion edema.

Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (IBM Corp, Armonk, NY). Qualitative data were described using number and percent. Quantitative data were described using range (minimum and maximum), mean and SD, and paired *t*-test. Significance of the obtained results was judged at the 5% level.

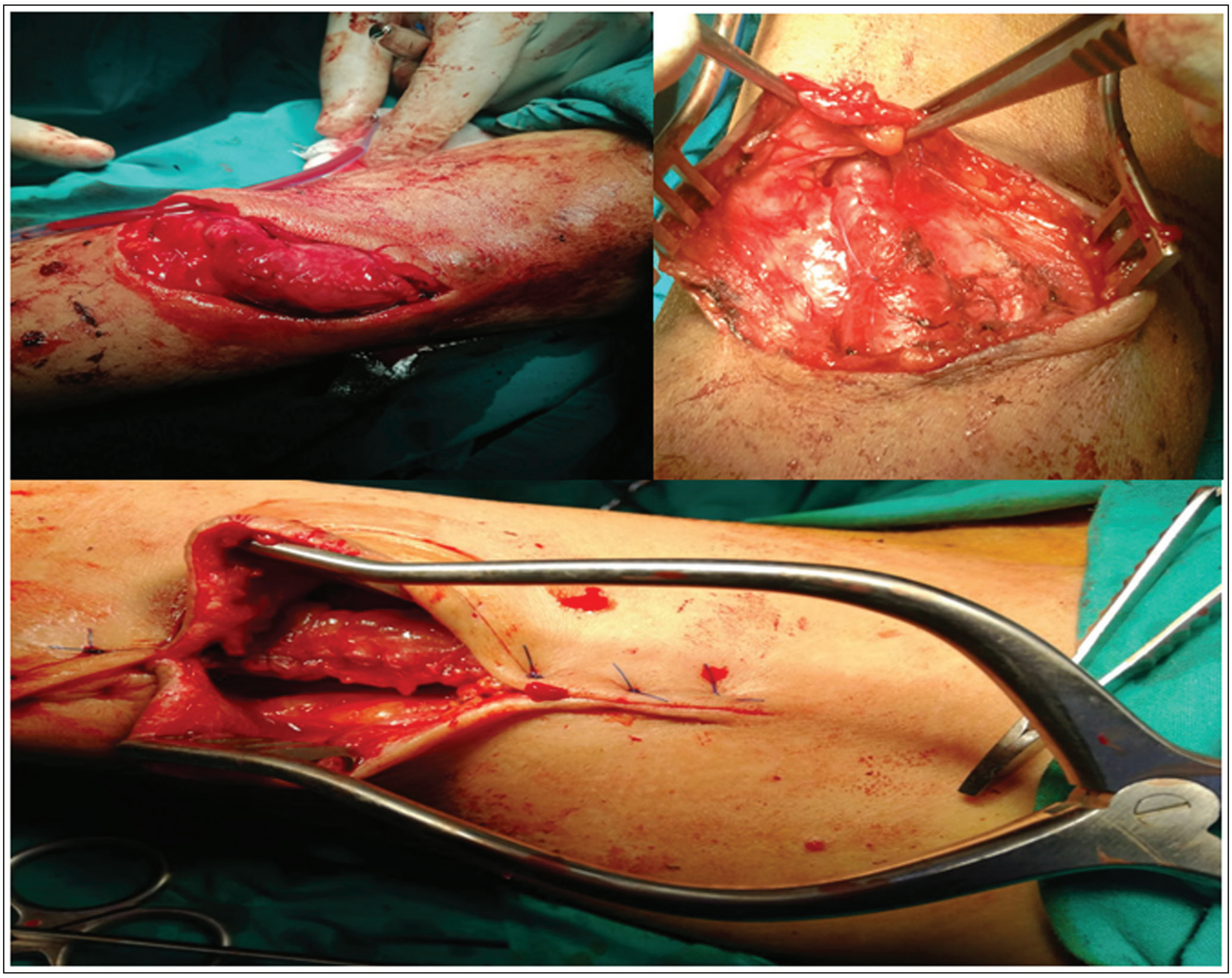
Results

The study included 20 ESRD patients on regular haemodialysis. They were 12 women (60%) and 8 men (40%). Their ages ranged from 18 to 63 years with a mean±SD of 48.26 ± 12.11 years (Table 1).

Fifteen of the studied patients had DM (75%), whereas 16 (80%) were hypertensive, 6 (30%) were smokers, 9 (45%) had ischaemic heart disease, and 2 (10%) patients had chronic obstructive lung disease. Nine patients (45%) had previous failed fistulae (Table 2).

Twelve of the study patients (60%) had hyperfunctioning brachiocephalic arm fistula as their vascular access,

Figure 4



Closure of the resized fistula by continuous polypropylene sutures.

Table 1 Patients sex and age distribution

Male patients, *n* (%)	Female patients, *n* (%)	Age range (years)	Age(mean±SD)
8 (40)	12 (60)	18–63	48.26 ± 12.11

Table 2 Patients comorbidities and previous access

Patients' comorbidities		History of previous access	
Diabetes mellitus	15 (75%)	Ipsilateral radiocephalic	2 (10%)
Hypertension	16 (80%)	Ipsilateral brachiocephalic	2 (10%)
Ischaemic heart disease	9 (45%)	Contralateral fistula	5 (25%)
Chest disease	2 (10%)	Previous ipsilateral central catheter	10 (50%)
Smoking	6 (30%)	Previous contralateral central catheter	20 (100%)
Total number (%)	20 (100%)	Total number (%)	20 (100%)

whereas the remaining eight patients (40%) had superficialized brachiobasilic fistulae. Their dialysis duration through these accesses ranged from 6 to 36 months with a mean±SD of 14.95 ± 8.82 months. These hyperfunctioning fistulae causing upper limb ischaemia comprises 2.89% (20 out of 690) of the native AVF done in a period of 2 years in the centers of the study after exclusion of heart failure, upper limb distal arterial disease, and major gangrene.

The patients main complaint was pain on dialysis (stage II) in 10 (50%) patients, whereas 9 (45%) complained of hand rest pain (stage III), and only 1 (5%) patient had limited gangrenous patch of two fingers (stage IV) (Table 3).

The mean preoperative fistula outflow FV was 1847.50 ± 656.04 ml/min. This was reduced postoperatively to a mean of 1258.50 ± 413.93 ml/min

Table 3 Patients' complaints and their clinical staging

Clinical stage of access-induced steal syndrome [9]	Description	Patients, *n* (%)
Stage I	Asymptomatic steal	0
Stage II	Pain on dialysis	10 (50)
Stage III	Rest pain	9 (45)
Stage IV	Tissue loss and gangrene	1 (5)

Table 4 Pre- and postoperative duplex changes in fistula outflow and wrist arteries

	Fistula outflow flow volume (FO-FV) ml/min	Maximum wrist artery peak systolic velocity (MW-PSV) cm/s
Preoperative (mean±SD)	1847.50±656.04	23.50±8.64
Postoperative (mean±SD)	1258.50±413.93	56.80±15.03
P value	0.002*	<0.002*

*Significance: $P<0.05$.

Table 5 Procedure outcome and complications

Assessment category	Patients, *n* (%)
Operative	
Bleeding	0 (0)
Nerve injury	0 (0)
Perioperative mortality	0 (0)
Clinical outcome	
Pain disappearance	15 (75)
Pain improvement	5 (25)
Healing of ischaemic lesions	1 (5)
Patency	20 (100)
Complications	
Limb loss	0 (0)
Wound infection	4 (20)
Swollen hand	10 (50)
Recurrence of symptoms	0 (0)
Reintervention	0 (0)

and this reduction was found statistically significant ($P=0.002$). On the contrary, a highly significant increase in the maximum wrist artery PSV was reported from a mean of 23.50±8.64 to 56.80±15.03 cm/s and a *P* value less than 0.002 (significance <0.05) (Table 4).

Operative success was achieved in all cases with no obvious complications as bleeding, nerve injury, or perioperative mortality. Clinical success was achieved in all cases (100%) with improved rest pain in 5 (25%) patients, and complete disappearance of rest pain in 5 (25%) patients (4 stage III patients and 1 stage IV).

Dialysis-related pain (50%) disappeared completely after the procedure. In addition, complete healing of the fingertip ulcers in one patient occurred (5%). These clinical results were obtained immediately postoperatively, after starting using fistula for dialysis, and during the short period of clinical follow-up (3 months) (Table 5).

During the follow-up period, 10 patients (50%) had swollen hands possibly attributed to revascularization. They were the patients classified as grade III (9 patients), and grade IV (1 patient). This edema was treated conservatively and improved markedly later. Four patients (20%) had mild to moderate surgical wound inflammation treated conservatively with empirical antibiotic use and healed soundly. No deep infection, no 2ry hemorrhage, and no limb loss were reported during follow-up. There were no recurrent ischaemic symptoms and no need for reintervention during follow-up (Table 5).

Discussion

The current study included 20 high flow steal patients due to hyperfunctioning arm AVFs in a 2-year period. This relatively modest number for such period was attributed to the low incidence of significant clinical presentation of such complication [6]. The exclusion of patients with distal arterial disease and AV grafts adds more to this limitation. This low number matches with similar studies reporting treatment of native fistulae steal [5,15]. However, a large study done by Miller *et al*. [16] reported 114 patients but this study was a retrospective one including both low and high flow steal patients and patients with AV grafts.

Similar to many studies [5,13,15], most of this studied patients were in the middle age group and this was attributed to the relatively healthy distal arterial tree of their upper limbs. Similarly, female patients predominance reported in this study may be explained by the exclusion of low flow steal cases that may be more in male sex. Similar studies treating hyperfunctioning fistulae reported similar sex difference [13], but this was not a constant observation. Schneider *et al*. [5] reported treatment of hyperfunctioning native fistulae in patients with male predominance but in older age group that might be the explanation of such sex predominance.

In all, 75%of the studied patients were diabetic, whereas 80% had hypertension. This matches with the general concept of ESRD etiology and gives a clue that is why 45% of them had previously failed access [17]. The indication of treatment was hand ischaemia, in all studied patients, due to hyperfunctioning native fistulae, 50% of them in stage II, whereas only one patient in stage IV (5%) [9].

In Schneider *et al*. [5], despite treating similar patients group, that is, hyperfunctioning native AVFs, the main indication was cardiac overload. They corrected this overfunction using synthetic T-shaped band to limit fistula outflow. This provided a proof that flow limitation was enough to correct both the heart failure and hand ischaemia. However, the current study excluded patients of heart failure mostly due to their late presentation rendering surgery intolerable to them. Another issue is that the policy in Alexandria University, the center of this study, is not to create fistula in patients with low cardiac reserve or heart failure. El-Laboudy *et al*. [13] enrolled similar patient group to the current study, with the same indication but the stages of ischaemia were more advanced.

Different techniques were used to treat steal syndrome. DRIL is exclusively used to treat hand ischaemia, whereas banding can deal with both hand ischaemia and heart overload 2ry to AV shunting [18,19]. Moreover, DRIL is a technically demanding procedure that is time consuming and carrying potential risk of interruption of the mail arterial supply to the hand. Similarly, PAI and RUDI carry the same risk besides using synthetic graft with the potential possible complications [20,21]. The technique in the current study did not use any synthetic grafting thus no synthetic material-related complications. Moreover, arterial reinflow or outflow anastomosis was not addressed in this technique; thus, it carries no interference with arterial anatomy of the limb treated.

Banding decreases AVF outflow by dealing with fistula venous limb and the juxta-outflow part of the shunt body and this basically keeps away from the arterial supply of the distal limb. It uses synthetic ring whether being a simple or T-shaped band with its potential risk of infection. Simple band is liable to prestenotic dilatation, band displacement with recurrent steal, and puncture site complications when band position is near [5]. Partial excision of AVF outflow and body was found similar to banding in being a simple way to decrease AVF outflow thus beneficial to treat fistula overfunction-induced hand ischaemia and cardiac overload as well but in a way not using synthetic band. It rather uses native tissue, narrowing the fistula by longitudinally suturing it after excising a part in a trial make a relatively durable outflow limitation. This limitation is not liable to displacement, predilatation, or injury during puncture.

In the present study, the reduction of the fistula outflow volume after partial excision was marked, from 1847.50 ± 656.04 ml/min preoperatively to 1258.50 ± 413.93 ml/min postoperatively and this drop was found statistically significant (P=0.002). This significant reduction matched well with similar drop after simple banding [13], T-banding [5], and the minimally invasive limited ligation endoluminally assisted revision (MILLER) banding [16]. On measuring wrist arteries and due to reversal of flow and technical issue, it was easier to measure wrist PSV that showed a highly significant increase from 23.50 ± 8.64 to 56.80 ± 15.03 cm/s (P<0.002) after partial shunt excision. On literature review, two studies measured wrist PSV in patients with AVF. One of them reported a significant relation between hand ischaemic symptoms and a wrist PSV below 40 cm/s [22]. The other one compared wrist PSV in dialysis patients without steal (mean of 55 cm/s) to that in patients suffering from dialysis-induced hand ischaemia (a mean of 36 cm/s) and found a significant difference between both (P=0.01) [23].

In the current study, partial AVF excision produced complete pain relief in 75% of studied patients, whereas 25% showed pain improvement that managed medically with satisfactory patients clinical response. The reported 1ry patency of the technique was 100% within 3 months postoperatively and zero reintervention rate. Similar clinical outcome was encountered in simple banding, T-shaped banding, and MILLER banding but with more complications and reintervention [5,13,16].

Miller *et al*. [16] reported operative technical failure due to bleeding that pushed the operator to abort the procedure in 3% of patients. Moreover, reintervention was done either for rebanding to treat inadequate clinical response in 6% of patients or to treat occlusion rendering a 2ry patency of 89% in 6 months, in the high flow steal group. Schneider *et al*. [5] reported 33% reintervension after T-banding to treat patients with high flow steal from native AVF, two thirds of them were rebanding. Similarly, El-Laboudy *et al*. [13] reported 5.3% rebanding rate after simple banding with another 5.3% converted to DRIL procedure due to inadequate response and fistula ligation in one patient as a limb salvage maneuver.

Conclusions

(1) Partial AVF excision is a feasible technique that offers strong fistula outflow narrowing that can treat steal due to hyperfunctioning fistula efficiently with minimal complications.

(2) It avoids interference with the natural arterial anatomy of the upper limb with its possible complications.
(3) It uses no synthetic material with its potential risk of infection.
(4) Unlike banding, with its different types, the technique entails longitudinal suturing of the fistula after resizing that does not slip and needs no repositioning.
(5) Continuous longitudinal suturing of this technique gives tight fibrotic circumferential narrowing of the AVF outflow that is claimed to offer a durable flow limitation that is expected to be patent by the residual flow determined during the sizing step of the procedure.
(6) The working group recommend long-term follow-up of these patients and more studies including patients suffering cardiac overload 2ry to hyperfunctioning fistulae.

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Conflicts of interest
The authors declare that there is nothing to disclose and no conflict of interest.

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