Is polytetrafluoroethylene circular banding an effective technique for treatment of high-flow vascular access-induced steal syndrome?

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Objective
The aim was to evaluate the efficacy and safety of polytetrafluoroethylene (PTFE) banding for treatment of high-flow vascular access-induced steal syndrome.
Patients and methods
The prospective study was conducted at Vascular Surgery Departments, Zagazig University Hospitals, Egypt and Alnoor Specialist Hospital, Makkah, Saudi Arabia from February 2016 to October 2019. The study included 19 cases (11 women). The mean age was 54 years. The access was brachiocephalic; arteriovenous fistula (AVF) in 11 patients, transposed brachiobasilic AVF in three patients and upper-arm synthetic in five patients. The mean duration of access was 1.2 years. Stages of steal were (stage II: three cases, stage III: nine cases, stage IV: seven cases).
Results
There was complete relief in 15 (79%) patients, while only partial improvement in four (21%) patients; one patient achieved complete relief with another banding, one patient continued to use his access with partial (but tolerable) symptomatic relief, one patient required distal revascularization and interval ligation, and the remaining patients underwent ligation. The average initial flow in native AVF was 2074 ml/min and in synthetic access was 2437 ml/min, and the average flow reduction after banding was 1025 ml/min (49%) in AVF and was 1247 ml/min (51%) in synthetic access. Only minor complications occurred in the form of cellulitis in two cases and mild bleeding in one case. Banding-related thrombectomy was done in three (16%) patients. Follow-up was for 1 year. Primary patency was 74 and 63% at 6 and 12 months, respectively, and secondary patency was 84 and 74% at 6 and 12 months, respectively.
Conclusion
PTFE banding is a simple technique to preserve the access function and treat symptoms of steal caused by high flow access. It is less time consuming, with lesser complications and accepted success rate and can be done as a day case procedure when compared with bypass techniques. So, PTFE banding can be used as an initial successful procedure for treating steal associated with high-flow access.

Keywords:
banding, high flow, steal syndrome, polytetrafluoroethylene

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Introduction

Creation of vascular access for hemodialysis leads to decreased hand perfusion, which is asymptomatic in most cases. Vascular access-induced steal syndrome (VASS) occurs in 1–2% of arteriovenous fistulas (AVFs) and 2.7–8% of arteriovenous grafts. It is defined as decreased perfusion distal to the access because of significant blood shifting into the access. Peripheral arterial resistance increases this blood shifting. Symptoms can be pain during dialysis or exercise (stage II), pain during rest (stage III), or, if not managed, steal can result in muscle atrophy and tissue loss in the form of ulcer or gangrene (stage IV). The important challenge in managing VASS is treatment of ischemia while preserving the access function. So, several techniques have been used for the treatment of VASS [1,2].

Surgical management can be classified into three types: ligation of the access, operations that limit the flow through the access, and operations that redirect the arterial inflow. Ligation is effective but leads to loss of access. Plication is used for flow limitation through the access and thus improving distal arterial flow; however, it has variable success in resolving the steal and preserving the access function. Redirection of arterial inflow includes distal revascularization and interval ligation (DRIL), revision using distal inflow (RUDI) and proximalization of the arterial inflow (PAI) which are long operations and have various complications [2,3].

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In DRIL, the artery is ligated just below the fistula with performing saphenous bypass from the artery above the fistula to the artery below the ligature. DRIL is not uniformly successful. Moreover, if bypass failed, the patient is liable for amputation [4]. While in RUDI, the anastomosis is ligated with taking arterial inflow from radial or ulnar artery by making anastomosis with the outflow vein either directly or by saphenous interposition or polytetrafluoroethylene (PTFE) graft [5]. In PAI, the outflow vein is ligated immediately after the anastomosis with taking arterial inflow from axillary artery to the outflow vein by smaller PTFE graft [6].

These bypass operations usually need general anesthesia for exposure and harvesting enough segment of vein leading to long operative time and postoperative hospital stay. There are many complications that were reported in the literature after these bypass operations. Also, one of the main disadvantages of bypass techniques is converting native fistula into prosthetic access, which is liable to infection, intimal hyperplasia causing stenosis and markedly less patency rates [4].

Banding is one of the operations that limit the flow through the access by applying high-resistance band to the low-resistance venous outflow. Different techniques of banding have been described but with complexities in sizing and design of the band with variable success rates [7]. In this study, a simple banding technique was assessed in treating steal syndrome and while maintaining the access function.

Patients and methods

We conducted our prospective study after approval of ethical committee at the Vascular Surgery Department, Zagazig University Hospitals, Egypt, and Vascular Surgery Department, Alnoor Specialist Hospital, Makkah, Saudi Arabia from February 2016 to October 2019. Our patients underwent history taking, physical examination, and laboratory investigations. All patients underwent Doppler ultrasound for flow measurement before and after banding.

Inclusion criteria

Chronic renal failure patients with elbow AV access either native or synthetic with high flow steal diagnosed as VASS:

(1) Stage II: pain during dialysis or exercise.
(2) Stage III: pain during rest.
(3) Stage IV: ischemic ulcer or gangrene.

With absent forearm pulsations and Doppler confirmation.

Exclusion criteria

Patients with complicated AVF such as aneurysmal dilatation, cardiac overload, or venous hypertension; patients with low flow steal and patients with peripheral arterial disease.

All patients were provided informed consent for banding. All cases were performed in the operating theater as day-case procedure under local anesthesia.

Surgical technique

All patients were operated upon under local anesthesia. After skin incision and subcutaneous dissection, the venous side just close to the anastomosis was hanged-up and freed from the surrounding tissues for 3–4 cm. Then a PTFE segment of 4–5 cm length and 6 mm diameter was longitudinally cut and wrapped circularly around the vein or the graft just beyond the anastomosis. The PTFE segment was sutured using 3–0 polypropylene sutures with an over and over technique (Figs 1 and 2). Tightness of banding was guided by flow measurement, by intraoperative Doppler (using superficial probe in sterile cover), on both outflow vein or graft (decreasing the flow to 40–60% of preoperative flow, keeping it at 800–1000 ml/min) and on radial artery (resuming PSV 50–80 cm/s and flow 100–150 ml/min with return of radial artery pulsations).

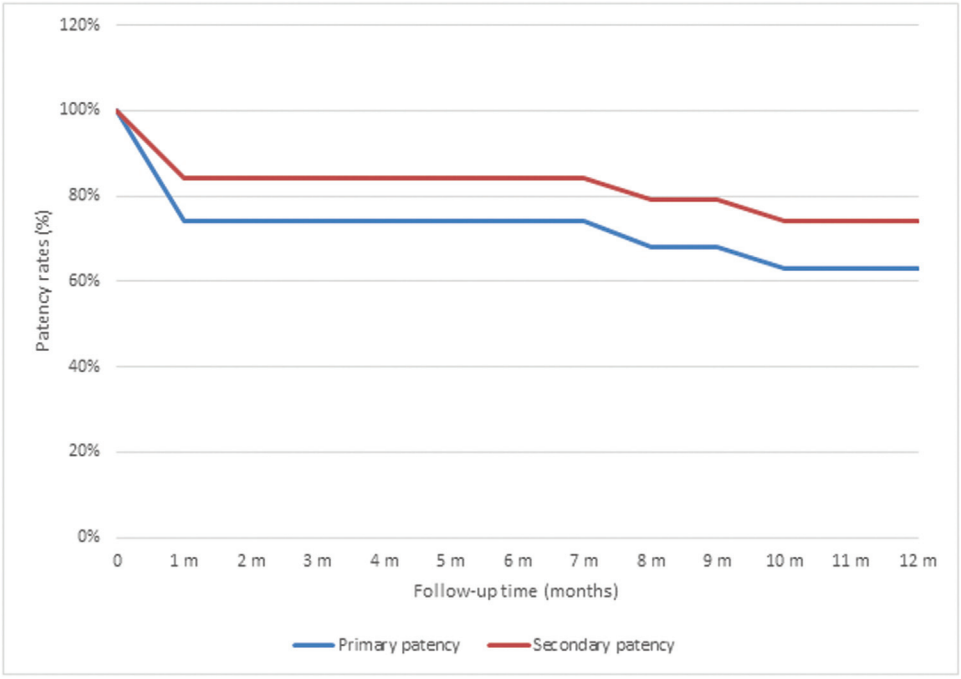
Results

Our study included 19 cases, 11 women and eight men. The mean age was 54±12.7 years (range: 32–75 years). Comorbidities were hypertension in 79%, smoking in 37%, dyslipidemia in 58%, ischemic heart disease in 47%, and diabetes mellitus in 68% (Table 1).

Eleven patients were hemodialyzed from brachiocephalic AVF, three patients were hemodialyzed from transposed brachiobasilic AVF, and five patients were hemodialyzed from upper-arm synthetic access. All patients were on regular hemodialysis for a mean of 1.3 years (range: 0.7–1.9 years), and the mean duration of access was 1.2 years (range: 0.6–1.7 years). Stages were classified as stage II: three cases, stage III: nine cases, and stage IV: seven cases (Table 2).

The whole operation time ranged from 35 to 60 min. Clinical success (complete symptomatic relief) with initial banding occurred in 15 (79%) patients, while

Figure 1



Steps of banding of outflow vein of brachiobasilic arteriovenous fistula.

Figure 2

Steps of banding of juxta-anastomotic graft of brachioaxillary arteriovenous graft.

only partial improvement occurred in four (21%) patients with initial banding, as the patients experienced only partial improvement. Of these four patients, one patient with synthetic access achieved clinical success with another banding operation, but with decreasing the diameter of the encircling PTFE segment (tighter). Of the remaining three patients, one patient continued to use his access under medical treatment of vasodilators with partial (but tolerable) symptomatic relief, one patient required DRIL, and one patient with brachiocephalic AVF underwent ligation because of increasing risk of gangrene. Banding-related thrombectomy (due to thrombosis within 1 month) was done in three (16%) patients; two with brachiocephalic AVF; and one of them with synthetic access. Two patients had successful thrombectomy and the remaining patient failed and underwent ligation. Primary patency after banding was

Table 1 Demographics and comorbidities

Variables	*N*=19 [*n* (%)]
Age (years) (mean±SD)	54±12.7
Sex	
Male	8 (42)
Female	11 (58)
Comorbidities	
Hypertension	15 (79)
Smoking	7 (37)
Dyslipidemia	11 (58)
Ischemic heart disease	9 (47)
Diabetes mellitus	13 (68)

Table 2 Access configurations and stage of steal

AV access	*N*=19 [*n* (%)]
Autogenous brachiocephalic AVF	11 (58)
Autogenous transposed brachiobasilic AVF	3 (16)
AV graft	5 (26)
Stage of steal	
Stage II	3 (16)
Stage III	9 (47)
Stage IV	7 (37)

AVF, arteriovenous fistula.

Table 3 Success and patency rates

Variables	*N*=19 [*n* (%)]
Success rate	
Clinical success	15 (79)
Clinical failure	4 (21)
Patency rate at 6 months	
Primary access patency	14 (74)
Secondary access patency	16 (84)
Patency rate at 12 months	
Primary access patency	12 (63)
Secondary access patency	14 (74)

74% and 63 at 6 and 12 months, respectively, and secondary patency was 84 and 74% at 6 and 12 months, respectively (Table 3 and Fig. 3).

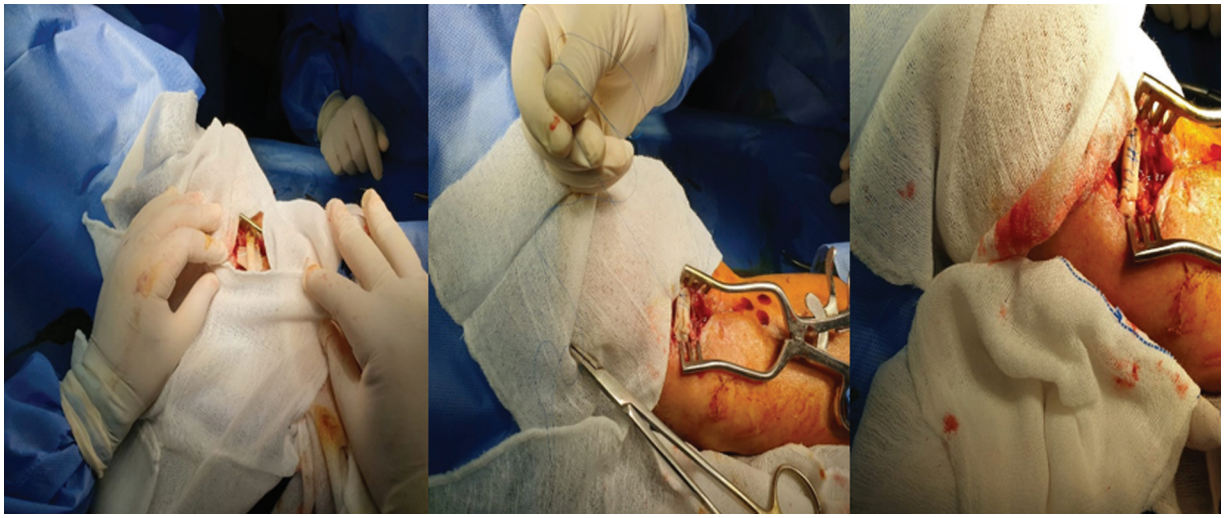
The average initial flow in patients with native AVF was 2074 ml/min and in patients with synthetic access was 2437 ml/min, and the average flow reduction after banding was 1025 ml/min (49%) in patients with AVF and was 1247 ml/min (51%) in patients with synthetic access. The patients were followed up for 1 year. Only minor complications occurred in the form of cellulitis in two cases; one with synthetic access and one with AVF (responded to medical treatment with antibiotics). Also, minor complications occurred in the form of mild bleeding in one case and was managed conservatively.

Discussion

The rate of upper extremity steal syndrome reported was 3.7–5% in dialysis patients. The variation of this rate depends on the type of AVF. Although the rate of steal syndrome in radiocephalic AVF was reported to be 1.8%, this rate increased to 10–20% in brachiocephalic or brachiobasilic AVF. High-flow steal syndrome is supposed to be due to wide anastomosis causing this high flow in the absence of peripheral arterial occlusive disease [8].

Numerous operations are found for the management of patients with steal syndrome. These treatment options included simple ligation of the fistula, flow-limiting procedures (plication, banding, anastomotic narrowing, and outflow reduction) and operations that redirect the arterial inflow like DRIL [9].

Figure 3



Primary and secondary patency rates.

Banding technique was first reported in 1975 by Anderson and Groce in three patients who were operated due to cardiac overload problem. The aim of this technique is to keep patency of AVF, while providing adequate distal perfusion [10].

In our study, all the 19 patients were on regular hemodialysis for a mean of 1.3 years (range: 0.7–1.9 years), and the mean duration of access was 1.2 years (range: 0.6–1.7 years). Our patients were referred late for AVF creation, mostly after starting dialysis, and the stage of steal was stage II in three cases, stage III in nine cases, and stage IV in seven cases. But, in a study done by Mestres *et al.* [11] which included 14 cases that were on regular hemodialysis for a mean of 1.1 years, the access was done 1.5 years earlier (reflecting early referral for AVF creation) and the stage of steal was stage II in two cases, stage III in eight cases, and stage IV in four cases.

In the present study, clinical success with initial banding occurred in 15 (79%) patients, while clinical success was not achieved in four (21%) patients of our initial bandings. Doppler before and after banding showed an average decrease of flow by 49%. But in a study by Miller *et al.* [12] which included 183 patients, clinical success with initial banding occurred in 91% while failed to produce complete symptomatic relief in 9%. The average decrease in flow was 50%. While in a study done by Mestres *et al.* [11], technical success was achieved in all cases, and the average decrease in flow was 39%.

Banding-related thrombectomy (due to thrombosis within 1 month) was done in three (16%) patients in our study. While in a study done by Gupta *et al.* [4], in which banding operation was performed in 22 cases, AVF thrombosis was observed in 19% of these patients after the banding procedure. This may be caused by tight banding to allow most of blood flow to adequately perfuse the hand for complete cure of steal, but this may lead to access thrombosis or insufficient access flow for efficient dialysis. The last two sequelae may occur also after banding of low flow access.

In a study by Yaghoubian *et al.* [13] plication was done for seven cases depending on the quality of Doppler signal on radial artery. All had immediate resolution of symptoms with 100% patency. One case needed re-plication. But this study had limited number of cases, and the surgeons depended on subjective measures like the quality of Doppler signal to determine tightness of plication.

In the past, banding was performed tightly because its main aim was to increase the resistance of access to shift the blood flow to distal arterial circulation. But this leads to reducing flow in the access markedly and may lead to access thrombosis. And so, many reports showed high rates of access thrombosis. But now intraoperative pressure or flow monitoring leads to improvement of the success of banding, while preserving access function [14].

In our study, tightness of banding was guided by flow measurement, by intraoperative Doppler on both outflow vein or graft (decreasing the flow to 40–60% of preoperative flow, keeping it 800–1000 ml/min) and on radial artery (resuming PSV 50–80 cm/s and flow 100–150 ml/min with return of radial artery pulsations).

Also, Ozbek *et al.* [15] had reported successful results with the banding technique by monitoring the pressure at the radial artery to decrease the risk of access thrombosis and to ensure adequate access flow. However, when blood flow through access was reduced enough to fix the steal syndrome completely with banding, thrombosis of the access is so common that it cannot be ignored at all.

In a study by Zamani *et al.* [16] which included 16 patients, distal arterial flow was assessed by digital plethysmography to get a digital pressure of more than 50 mmHg and also a digital pressure to brachial pressure index of more than 0.69. This technique relieved steal symptoms in all cases, but only 10 (63%) had functioning access for greater than 6 months.

Also, in a study by Zanow *et al.* [17] which included 78 cases of high flow steal, plication of the vein or the graft close to the anastomosis for 2–3 cm with continuous polypropylene 6–0 sutures was done, then when the determined access flow was achieved, a PTFE strip was wrapped and sutured around the narrowed segment of the vein or the graft to decrease the fistula flow to 400 ml/min, and to 600 ml/min in synthetic grafts; thus symptoms were relieved in 86% of cases, with 91% patency of fistulae and only 58% patency of synthetic grafts at 1 year. Authors suggested that a higher flow rate (>750 ml/min) in synthetic graft was needed to prevent access thrombosis.

Recently, the minimally invasive limited ligation endoluminal-assisted revision technique was described by Miller *et al.* [12], where the access is exposed and a 4–5 mm balloon is introduced into the outflow vein near the anastomosis and inflated. A nonresorbable suture is then tied around the inflated

balloon and vein. All his cases had improvement in symptoms, two needed later revision with 100% patency at 3 months. But this technique requires combined endovascular and open surgical approach. In a study by Gupta *et al.* [4], 87 operations were performed in 70 cases of VASS. The operations were DRILL in 21 cases, PAI in four cases, improvement of proximal inflow in nine cases, RUDI in four cases, banding in 22 cases, and ligation in 27 cases. In spite that DRIL had a higher success than banding, DRIL is not uniformly successful, usually needs general anesthesia for exposure and harvesting enough segment of the vein leading to long operative time and postoperative hospital stay. Moreover, if bypass failed, the patient is liable for amputation. There are many complications that were in reported in the literature including failure of hand salvage after DRIL and in their study, Gupta *et al.* [4] reported amputation after DRIL and repeated debridements for a case of VASS. One of the main disadvantages of bypass techniques is converting native fistula into prosthetic access which is liable to infection, intimal hyperplasia causing stenosis, and markedly less patency rates [4].

Conclusion

PTFE banding around the juxta-anastomotic vein or graft is a simple technique to preserve the access functioning and to treat symptoms of steal caused by high flow access in most patients. It is less time consuming, with less complications and accepted success rate and can be done as a day case procedure if compared with bypass techniques which may have higher success rate, but they are complex, time consuming, liable to more complications, and need longer duration of hospitalization, so, PTFE banding can be used as an initial successful procedure for treating steal associated with high flow access.

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Nil.

Conflicts of interest
There are no conflicts of interest.

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