Banding between dialysis puncture sites to treat severe ischemic steal syndrome in low flow autogenous arteriovenous access

David Shemesh, MD, Ilya Goldin, MD, and **Oded Olsha, MBBS,** *Jerusalem, Israel*

Dialysis-associated steal syndrome with rest pain and ischemic nonhealing ulcers dictates prompt surgical intervention. Distal revascularization with interval ligation is extensive surgery for frail patients in whom calcified distal arteries make anastomosis difficult. Simple banding is appropriate in high-flow fistulas. In low-flow accesses, further flow reduction by simple banding may result in inadequate dialysis and cause thrombosis. However, banding between puncture sites maintains a pressure gradient between the arterial and venous puncture sites that enables adequate flow with effective hemodialysis that would not be possible with banding at the anastomosis. This new technique is a good solution for maintaining access patency and increasing digital pressure while avoiding complicated surgical revisions in high-risk patients. (J Vasc Surg 2010;52:495-8.)

Half a century after the introduction of the autogenous arteriovenous access by Brescia, Cimino, Appel, and Hurwich, this is still the best approach for chronic hemodialysis in end-stage renal disease (ESRD) patients.[1] The prevalence of ESRD is increasing along with the age of our patients as well as the duration of chronic hemodialysis therapy in these patients.[2] Diabetes mellitus is the most common etiology of ESRD, and complications of arteriosclerotic peripheral vascular disease should be anticipated in these patients and in elderly patients undergoing hemodialysis.

Patients with critical hand ischemia related to dialysis-associated steal syndrome (DASS) need prompt surgical intervention. They may present with pain at rest, nonhealing wounds, digital gangrene, or neurologic damage. Treatments for DASS include access closure, blood-flow reduction surgery, and ligation of the source of steal with distal revascularization. Simple banding guided by quantitative Doppler ultrasound imaging may improve hand perfusion, while reducing blood flow in the access to the minimum flow needed to maintain patency.[3]

In some patients with DASS, however, measures to limit blood flow have already been applied intraoperatively by the construction of a narrow arterial anastomosis in an autogenous arteriovenous access because of a reasonable anticipation that steal will develop, and the blood flow is already at the minimum level necessary for efficient hemodialysis. Banding at the anastomosis to produce further blood flow reduction in these patients may severely reduce the effectiveness of hemodialysis, even if patency is maintained, and increases the risk of thrombosis.[4,5]

We describe a new technique of banding between dialysis puncture sites for patients with DASS who have autogenous arteriovenous accesses with low flow and who require an increase in digital arterial pressures while maintaining a pressure gradient between the puncture sites that is sufficient for effective hemodialysis despite the attendant flow reduction.

DETAILS OF THE PROCEDURE

All patients enter our routine access surveillance program.[6] For autogenous access, the patients are examined clinically and with color-coded Doppler ultrasound imaging (Acuson Sequoia 512, Mountain View, Calif with a 6L3 multifrequency linear array transducer, which was replaced by a Philips iU22, Bothell, Wash with an L9-3 broad-spectrum linear array transducer in 2008). Examinations are done at 1, 6, and 12 months, and then every 12 months as long as no problems are identified. Patients with problematic accesses are examined every 3 months, as was the case with the patients described herein.

Imaging. Hemodialysis patients with steal syndrome were assessed by Doppler ultrasound imaging and angiography. Steal syndrome was diagnosed by the appearance of ischemic symptoms, rest pain, and/or ulceration in the fingers.

Patients with steal caused by proximal arterial stenosis were treated with angioplasty and stenting when necessary, and these patients were not included. Only in patients without proximal arterial stenosis were maneuvers done to compress the fistula with Doppler ultrasound imaging to improve digital flow while maintaining adequate flow for hemodialysis. The flow volume in the fistula was calculated by multiplying the time-averaged mean velocity by the cross-sectional area of the ipsilateral brachial artery minus

From the Department of Surgery, Vascular Access Center, Shaare Zedek Medical Center (affiliated with the Faculty of Medicine of the Hebrew University).

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Correspondence: Dr Ilya Goldin, Vascular Access Center, Department of Surgery Shaare Zedek Medical Center, PO Box 3235, Jerusalem 91031, Israel (e-mail: migoldin@gmail.com).

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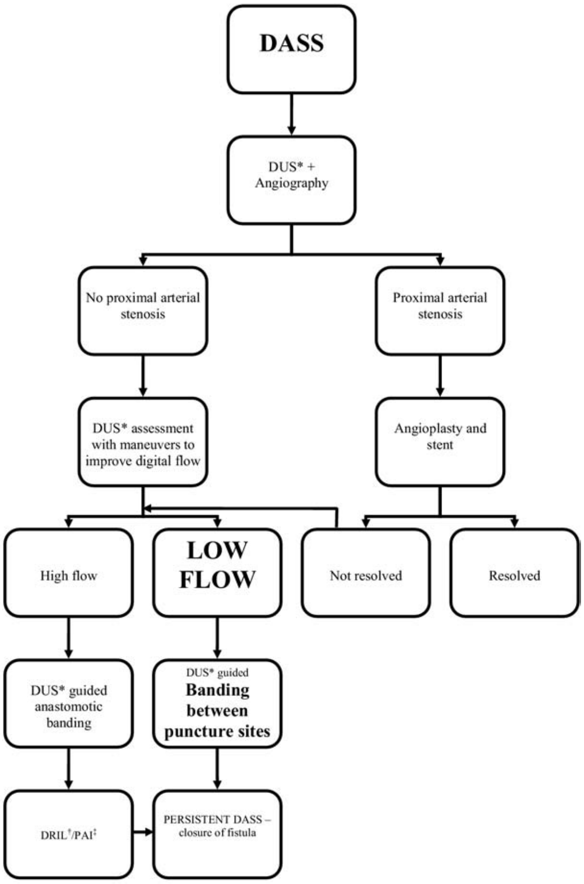

Fig 1. Algorithm describing selection of patients with dialysis-associated steal syndrome *(DASS)* for banding between puncture sites. †*DRIL,* Distal revascularization-proximal ligation; **DUS,* Doppler ultrasound; **PAI,* proximalization of the arterial inflow.

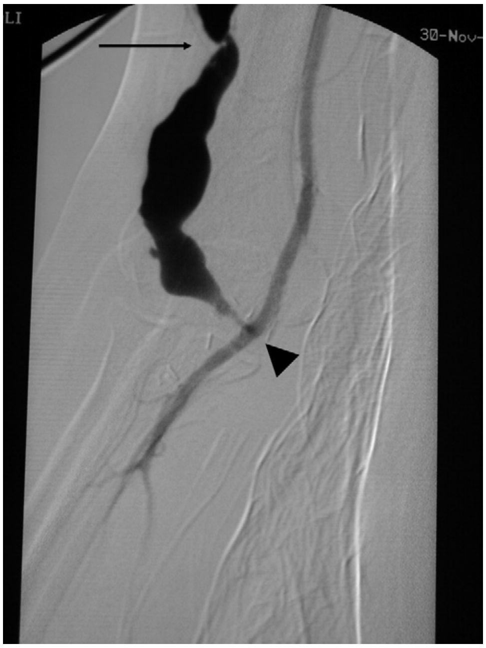

Fig 2. Angiography demonstrates a deliberately constructed narrow anastomosis *(arrowhead)* to prevent steal in a patient who nevertheless developed steal that was subsequently treated by banding between the puncture sites *(arrow)*.

the cross-sectional area of the contralateral brachial artery. The blood flow in the fistula was gradually reduced by manual compression until a digital pressure of at least 60 mm Hg and/or a digital/brachial pressure index of ≥0.5 was attained, to a minimum flow of 350 mL/min.[7] Digital pressure was measured with a digital blood pressure cuff and a Doppler probe. If these results could not be achieved with a minimum flow of 350 mL/min, then more complex surgical interventions or access closure had to be considered.

The criteria for surgical intervention were rest pain or nonhealing ischemic ulcers, or both. The Doppler ultrasound examinations were done as part of the assessment and planning for any intervention that might be required. Patients in whom adequate flow for hemodialysis of >800 mL/min could be maintained with improvement in digital flow were referred for Doppler ultrasound-guided banding at the anastomosis; if banding failed, more complex surgical procedures such as distal revascularization-proximal ligation (DRIL) or proximalization of arterial inflow (PAI) could be still done. Those in whom an adequate flow of >800 mL/min could not be maintained during manual compression were sent for banding between the puncture sites if a digital pressure of at least 60 mm Hg and/or a digital/brachial pressure index of ≥0.5 could be attained with a flow of >350 mL/min. These patients are the subject of this study (Fig 1).

Technique of banding between the hemodialysis puncture sites. All patients in the study were thought to be at high risk for steal before initiation of hemodialysis because of the presence of severe vessel calcification associated with diabetes or their advanced age. Their original accesses were therefore deliberately constructed with a narrow anastomosis (Fig 2).

At surgery, intraoperative Doppler ultrasound imaging was used for quantitative blood flow measurement. The access was narrowed between the arterial and venous puncture sites using the banding technique[8] to attain the blood flow that was achieved in the preoperative simulation to reach the desired index and digital pressure that was accompanied by a sharp Doppler digital trace.

We used a 5-mm-wide strip of expanded polytetrafluoroethylene (ePTFE) Gore Cardiovascular Patch (W. L. Gore and Associates, Flagstaff, Ariz) to form a cuff around the vein. The cuff was tightened until the desired flow was achieved according to intraoperative Doppler ultrasound imaging. The cuff was sutured with CV6 TT9 ePTFE sutures (W. L. Gore and Associates).

Follow-up. All patients re-entered the surveillance program as described above.

CLINICAL EXPERIENCE

From January 2001 to December 2007, we constructed 1629 new accesses and completed an additional 294 surgical revisions for various reasons. Seven patients had surgery for steal syndrome associated with low access flow (2% of all surgical revisions). Five had a brachial cephalic autogenous access, one had a brachial-to-transposed basilic vein autogenous access, and one had a radial-to-cephalic autogenous access. Patients were a mean age of 61 ± 14 years (range, 38-72 years) at the creation of the original access. Five patients had frank ischemic ulceration or gangrene (with or without resorption of a digit), and two had rest pain, of which one had cyanotic fingers. The patients were treated 11.6 ± 10.2 months (range, 4-34 months) after the initiation of dialysis. All were diabetic and had symptomatic peripheral occlusive disease. Two had undergone lower limb amputations. All patients who had banding between puncture sites for low access flow during this period were included in this study.

The mean blood flow in the accesses was 810 ± 129 mL/min (range, 632-983 mL/min) and was decreased surgically to 558 ± 133 mL/min (range, 363-802 mL/min; $P = .0053$, paired *t*-test). There were no surgical failures. Efficient hemodialysis was maintained in all patients. All ulcers healed within 1 to 3 months postoperatively, and the symptoms resolved.

Increased narrowing at the banding site in two patients was treated by prophylactic angioplasty, with no further deterioration. Three patients died at 41, 20, and 10 months after correction of steal with a patent access, and the other four still had a patent access at 6 to 43 months after surgical correction of steal by banding between the puncture sites. At long-term follow-up, the access diameter was 16.1 ± 2.6 mm at the arterial side and 15.5 ± 3.9 mm at the venous side, with an arterial/venous diameter ratio of 1.1:1. Mean follow-up for the entire group was 23 ± 14 months (range, 6-41 months).

DISCUSSION

Vascular calcification causing distal arteriopathy is an important factor that may contribute to the development of symptoms of arterial steal syndrome. Patients undergoing hemodialysis access construction should be assessed for risk factors for the development of steal syndrome, such as extreme old age, diabetes, multiple access procedures, duplex ultrasound findings suggestive of severe distal arteriosclerosis, and constructions based on proximal arteries.[9] As with all the patients in our study, a deliberately constructed narrow anastomosis can be done to diminish the risk in patients considered to be at high risk for developing DASS.

Some degree of ischemia causing pain or paresthesias occurs in 10% to 20% of patients after access construction.[9] Patients with mild symptoms, including paresthesia, coolness, and the absence of distal pulses can be closely observed because many of these symptoms will resolve. Severe, persistent steal with ulceration and tissue loss occurs in 2% to 6% of hemodialysis patients[10] and is associated with diabetes and increasing age. Averaged over all access types, the risk for peripheral ischemia accounts for seven events per 100 patient-years at risk in diabetic patients, which is significantly higher than for nondiabetic patients.[11] Overall, there is a 4% incidence of severe ischemia requiring reintervention.[9]

Techniques for correcting steal include percutaneous transluminal angioplasty, banding or restrictive procedures, DRIL and its modifications, PAI, and arteriovenous fistula ligation. We have determined that banding at the anastomosis is suitable in patients with a flow of >800 mL/min. The minimal blood flow necessary is not well established, but others have also used this cutoff.[12] However, this minimum flow may still be too low for banding at the anastomosis if the blood pressure falls precipitously during hemodialysis.

Operative intervention for ischemic steal syndrome successfully resolves ischemia in 80% to 95% of patients.[9] Revascularization procedures are considered the best option,[13] but these are extensive procedures that need to be done in patients who are typically frail and have calcified arteries that make an anastomosis difficult. Furthermore, in the setting of low flow steal, failure of DRIL because of technical problems at the anastomosis or intrinsically poor outflow would put the limb at risk. PAI is a lesser insult to these frail patients than DRIL, but banding between puncture sites is still a smaller procedure. Unlike PAI, banding between puncture sites does not preclude doing larger procedures at a later date and does not convert an autogenous access to a graft.

Doppler ultrasound imaging is now commonly used for quantitative blood flow reduction with preservation of access patency to improve DASS.[3,7] Blood flow in an autogenous access should be >600 mL/min for efficient hemodialysis but can decrease to 300 to 500 mL/min while still maintaining access patency.[14] The blood flow in most patients exceeds this value and simple banding guided by quantitative Doppler ultrasound imaging may improve hand perfusion while reducing blood flow in the access to the minimum flow needed to maintain patency.

In some patients with DASS, however, measures to limit blood flow have already been applied intraoperatively by the construction of a narrow arterial anastomosis because of a reasonable anticipation that steal will develop and the blood flow is already at the minimum level necessary for efficient hemodialysis. DASS in the presence of low flow presents a particular problem because banding at the anastomosis may cause inefficient hemodialysis or occlusion of the access.

Each treatment option has its drawbacks. Access closure is the last measure that should be considered because it risks the possibility of running out of access options earlier and requires the construction of a new access that may then not be feasible. Surgical bypass (DRIL) to alleviate the relative arterial insufficiency entails major surgery in a population that usually has significant comorbidity and leaves the blood supply to the hand totally dependent on the bypass. Nonquantitative Doppler ultrasound imaging and photoplethysmography[8] may lead to over-compression or under-compression of the access. Nonquantitative and quantitative techniques of banding at the anastomosis both risk a reduction of flow that may make dialysis inefficient or cause the access to occlude. Constrained stents placed percutaneously within the access[15] cannot be controlled in real time.

CONCLUSIONS

This study concerns a select group of diabetic patients with severely calcified arteries in whom DASS was anticipated at the initial access construction, which was done with a narrow distal anastomosis to prevent this specific complication. All of the patients had rest pain or ischemic ulceration, or both, requiring prompt surgical intervention. This problem may be expected to increase with the growing number of older and diabetic patients beginning hemodialysis.[2] Banding between puncture sites maintains a pressure gradient between the arterial and venous puncture sites that enables efficient dialysis with adequate flow that would not otherwise be possible if the banding was performed at the anastomosis. In our patients, there was only mild dilatation at the arterial puncture site compared with the venous puncture site (1.1:1) at long-term follow-up. Banding at this point is a good solution for high-risk patients with low-flow accesses if it increases digital pressure >60 mm Hg. This technique can maintain access patency while avoiding complicated surgical revisions.

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