Advances in Surgery 53 (2019) 83–101
ADVANCES IN SURGERY

Management of Difficult Dialysis Access Issues for Dialysis Patients

Matthew J. Dougherty, MD[a,*], Douglas A. Troutman, DO[a], Krystal C. Maloni, MD[b]

[a]Section of Vascular Surgery, Pennsylvania Hospital, University of Pennsylvania, 700 Spruce Street, Suite 101, Philadelphia, PA 19106, USA; [b]Pennsylvania Hospital, University of Pennsylvania, 700 Spruce Street, Suite 101, Philadelphia, PA 19106, USA

Keywords

• Arteriovenous fistula • Arteriovenous graft • Tunneled dialysis catheter • Stenosis • Thrombosis • Steal syndrome • Erosions • Aneurysm

Key points

- The demand for hemodialysis access is increasing and many challenges remain.
- Improvements in prevalence of autogenous access has not reduced the need for improvements in maintenance and treatment of complications of hemoaccess.
- The usefulness of endovascular technologies has increased, but surgical therapies will remain important for the foreseeable future.

HEMODIALYSIS ACCESS

Tunneled dialysis catheters

Tunneled dialysis catheters (TCD) are an essential component of the dialysis access armamentarium, despite many shortcomings [1]. These devices serve as a nidus for infection, stenosis, and thrombosis, and are associated with more complications than any other mode of dialysis access. TCD use often comes down to necessity, allowing for immediate use. They are often used as a bridge until more durable hemoaccess is achieved. Eighty percent of US patients initiate hemodialysis with TCDs, and mean time of TCD dialysis exceeds 3 months [2].

Disclosure Statement: The authors have nothing to disclose.

*Corresponding author. *E-mail address:* mdougherty@pavascular.com

https://doi.org/10.1016/j.yasu.2019.04.005
0065-3411/19/

The preferred site for TCD placement is the right internal jugular vein, because of better patency, likely reflecting a straighter path to the superior vena cava (SVC) than the left jugular vein [3]. Subclavian veins should rarely be used, as approximately 50% will develop stenosis that will complicate upper extremity access [3]. For patients who have exhausted conventional sites for access, transhepatic and translumbar catheters can be considered [4,5].

Arteriovenous fistula

Since its first description in 1966, the creation of an accessible primary arteriovenous fistula (AVF) has been considered the first option for hemoaccess [6]. Duplex vein mapping is essential to hemoaccess planning. Larger vein size correlates with increased maturation success as well as long-term patency [7]. A vein diameter greater than 3 mm is generally sufficient, provided adequate arterial inflow is obtained. When planning for hemoaccess, dialysis dependence should be a consideration. Patients on dialysis with a TCD may require months of catheter use awaiting AVF maturation. Upper extremity access is much preferred to lower extremity options, as the latter entail more complications and morbidity.

The radiocephalic fistula is the best first choice, as it does not compromise more proximal future options. A brachial-cephalic fistula is the most common conformation in today's dialysis population. The brachial-basilic transposition fistula has increased in prevalence in the last 2 decades. There remains controversy as to whether staging the transposition procedure is beneficial [8].

Obesity poses a challenge in AVF creation [9]. Increased subcutaneous tissue and depth of veins increases the technical challenge of the surgery and decreases the likelihood of optimal cannulation. These patients may require a secondary superficialization procedure such as lipectomy, liposuction, and/or surgical elevation; prolonging maturation time [9].

Lower extremity access is often pursued after upper extremity options have been exhausted, generally in the setting of central venous occlusion. The saphenous vein is a poor autogenous option, but femoral vein transposition is a durable, albeit morbid, option [10].

Although surgical AVF construction generally involves minimal incisional morbidity, percutaneous techniques of establishing autogenous access have been developed and are of increasing interest, with early results that seem promising [11].

Arteriovenous grafts

For patients who do not have adequate vein for fistula creation in the upper extremity, an arteriovenous graft (AVG) can be constructed. AVGs can be configured in either looped or straight conformation, and tunneled in a fashion to allow for convenient cannulation and hemostasis. The brachial artery is most commonly used for inflow.

More exotic options for AVG placement include brachial artery to jugular vein, axillary artery to contralateral/ipsilateral jugular or axillary vein. Patency has been reported to be equivalent to upper extremity grafts, with fewer

complications than lower extremity AVGs [12]. Lower extremity AVGs are generally constructed in the thigh, and carry higher risks of infectious and ischemic complications than upper extremity grafts [13,14]. Avoidance of a groin incision with lower extremity AVGs construction may reduce infection risk.

The "Fistula First" effort spearheaded in the United States by the National Kidney Foundation in 2003 aimed to reduce TCD and AVG use, and the complications associated with these. The effort successfully increased autogenous access prevalence in the United States from 22% to 58% [15]. However, this approach has resulted in a significant primary failure rate for autogenous access, which has prolonged catheter use time. Patients with borderline vein quality and limited life expectancy may be better served by graft construction, especially in the octogenarian population [2].

Conduit options for arteriovenous graft

Considerations for graft material include size match, mechanical strength, thrombogenicity, tissue incorporation, ease of handling, resilience to repeated punctures, infection, myointimal hyperplasia, resistance, and cost. Biologic (primarily bovine xenograft) and prosthetic conduits (dacron and expanded polytetrafluoroethylene [PTFE]) have been used for nearly 5 decades. Multiple modifications have been attempted at improving primary patency rates, which remain poor, averaging 6 months or less [16].

PTFE has been by far the most common prosthetic material used; however there are several alternatives and modifications available. These include carbon coating, heparin binding, and multilayer design for early cannulation. Biologic grafts commercially available include bovine mesenteric vein (ProCol, LeMaitre); bovine ureter (SynerGraft, CryoLife); and bovine carotid artery (Artegraft). Human cryopreserved allografts have also been used in limited applications (CryoLife).

For xenografts, the bovine carotid graft has been received most recent attention. A small but provocative randomized trial demonstrated a large patency advantage compared with PTFE [17]. Several larger series in the last few years have also suggested, but not proven, possible patency and infection advantages over PTFE [18,19]. Early cannulation, often within 24 hours, has been used in 1 report (UCLA data), which may avoid the need for catheter access [20].

Tissue-engineered grafts

An area of ongoing interest is the development of a bioengineered vascular conduit. No such conduits are currently commercially available, but phase 2 and 3 trials are underway. These consist of tissue-cultured conduit scaffolds that have been implanted with some success [21]. This may prove a promising alternative to currently available prosthetic materials, with their manifest limitations of poor patency.

Arteriovenous fistula versus arteriovenous graft

AVFs experience higher patency and lower reintervention rates than AVGs, in the range of a 2- to 4-fold advantage. However, high primary maturation

failures for AVF skews these data, and individual considerations should influence access choice [22]. Advanced age has been identified as a risk factor for failure of maturation of fistula and decreased patency [23]. In 1 series, patients over 65 had a 1.7 relative risk of maturation failure compared with younger patients [24], and radial-cephalic AVF do poorly in patients over 75 [25]. Longevity and frailty are important considerations [26,27]: 2-year mortality exceeds 50% in patients initiating dialysis over the age of 75 years (Fig. 1) [27,28].

COMPLICATIONS

Thrombosis/stenosis

Of complications and problems associated with hemoaccess, none is more prevalent than the development of stenosis and occlusion of these circuits. The biology is different than observed with arterial bypass grafts, and patency results are far inferior. Although surveillance to identify stenosis before occlusion is an attractive concept, no patency advantage has been demonstrated with routine duplex surveillance protocols for hemoaccess [29].

Clinical monitoring for efficacy of dialysis, excessive pulsatility, puncture site bleeding, recirculation, or other evidence of declining access function, is the usual approach to identify hemoaccess that warrants imaging. In the last 2 decades, endovascular treatment has supplanted surgical revision as first-line therapy for most patients. In the setting of hemoaccess occlusion, despite previous trials suggesting superior results with surgical treatment, catheter-based intervention is first choice for secondary patency, primarily due to decreased morbidity and easier access to intervention facilities than the operating room [30–32].

There are a variety of mechanical thrombectomy catheters used to restore hemoaccess patency. These include the AngioJet catheter (Boston Scientific, Watertown, MA), Arrow-Treratola Device (Teleflex, Inc, Morrisville, NC),

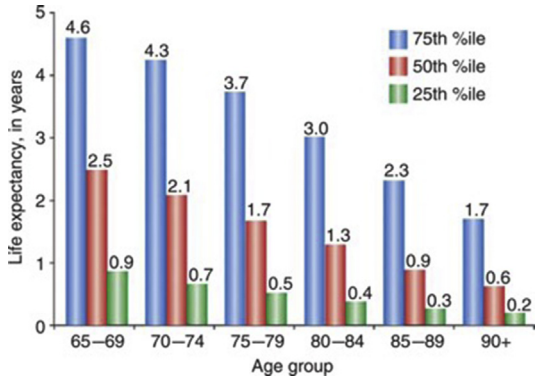

Fig. 1. Life expectancy in years after initiating dialysis. (*From* Tamura MK, Tan JC, O'Hare AM. Optimizing renal replacement therapy in older adults: a framework for making individualized decisions. Kidney Int. 2012;82:262; with permission.)

and Penumbra catherer (Penumbra, Inc, Almeda, CA). Thrombolytic agents, combined with catheter aspiration have also proved effective for declotting hemoaccess. Most thromboses are associated with an underlying stenotic lesion, which is then treated with balloon angioplasty. As lesions tend to be fibrous in nature, elastic recoil is common. High-pressure and cutting balloons may offer advantages, but stenting is sometimes needed to achieve technical success [33].

In the early 1990s, comparative studies of primary bare metal stenting demonstrated no long-term benefit compared with angioplasty alone; however, several recent randomized trials have documented the superiority of covered stents to angioplasty alone when treating lesions in patients with dialysis grafts [34–36]. A recent randomized trial looking specifically at treatment of in-stent stenosis in AVFs likewise showed superiority of stent graft treatment compared with angioplasty alone (Fig. 2) [36,37].

There are no randomized controlled trials comparing stent grafts to bare metal stents, which is unfortunate given the marked cost difference (covered stents are approximately double the cost of bare metal stents). Recurrent myointimal hyperplasia is the primary cause of hemoaccess failure, whether treated with angioplasty alone or stented. Therefore, drug-eluting stents and drug-coated balloons offer promise in this regard, although data are still limited (Fig. 3) [38,39].

Central venous stenosis and occlusion can be difficult to treat. The 2 most common factors causing central stenosis or occlusion are the presence of pacemaker leads and the prolonged use of TCDs. These lesions at the central level are less likely than peripheral lesions to precipitate hemoaccess thrombosis. More typically they cause increased venous pressure, prolonged access site bleeding, recirculation, upper extremity edema, as well as cervicocephalic edema (sometimes SVC syndrome).

Percutaneous intervention is the preferred approach for central venous stenosis/occlusions, but recurrent stenosis is common and often leads to multiple interventions. A venous area particularly prone to development of stenosis is within the subclavian vein at the thoracic inlet. Because of extrinsic compression, these are often recalcitrant lesions. Stents should be avoided as they are prone to fracture due to extrinsic forces. Surgical decompression with first rib excision can be used, but is often also avoided in these patients because of considerable comorbidity [40].

Central venous occlusions have been a recent focus of attention. Recanalization (laser, radiofrequency, and sharp needle) have been combined with stent graft or HeRO device deployment to allow for continued upper extremity dialysis access [41]. The "inside out" approach has been described, accessing the SVC via the femoral vein. A long sheath and dilator are advanced with a stiff wire into the cervical soft tissue. The wire is retrieved and a sheath advanced from above, through which a TCD or HeRO device can be advanced into the SVC [42].

Infection

Infection is the second leading cause of mortality in dialysis patients, accounting for 15% to 20% of deaths, with about 20% of these infections due to

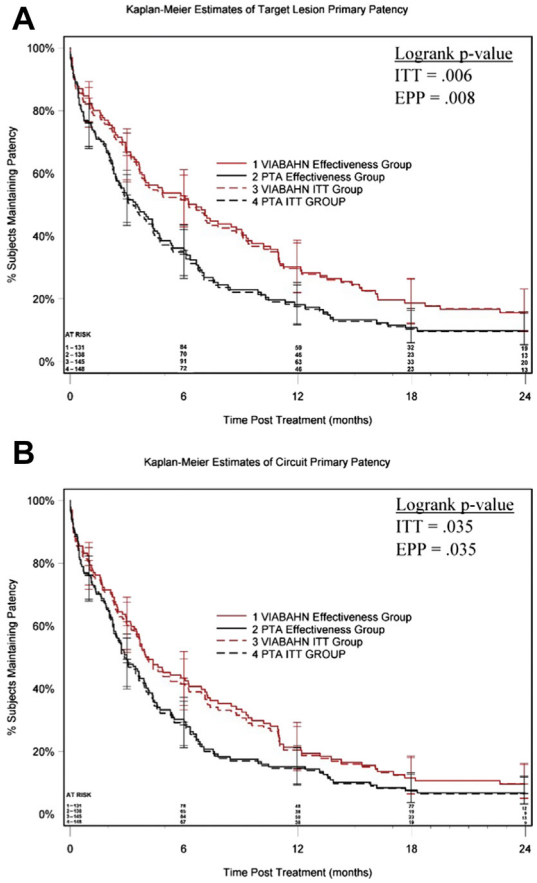

Fig. 2. Stent grafts improve primary patency of target lesion and access circuit compared with balloon angioplasty. (*A*) Kaplan-Meier estimates of primary patency of the target lesion and (*B*) access circuit. In all cases, stent grafts demonstrated statistical superiority in patency compared with balloon angioplasty. (*P* values shown in each panel were calculated using the log-rank test.) EPP, effectiveness-per-protocol; ITT, intention to treat; PTA, percutaneous transluminal angioplasty. (*From* Vesely T, Davanzo W, Behrend T, Dwyer A, Aruny J. Balloon angioplasty versus Viabahn stent graft for treatment of failing or thrombosed prosthetic hemodialysis grafts. Journal of Vascular Surgery. 2016;64(5): 1408; with permission.)

hemoaccess [43]. TCD infections are very common, and when associated with bacteremia, are best treated with removal of the infected catheter and antibiotic therapy. It is important to remove infected TCDs in a timely matter to help prevent bacterial seeding of other prosthetic implants. Catheter salvage rates are poor (25%–32%) with antibiotic treatment alone [15,44].

AVFs have the lowest infection risk, whereas infection rates of 4% to 17% have been reported for AVGs [15,18]. Biological grafts may confer a lower infection risk than prosthetic grafts [18]. Location of AVG implantation also

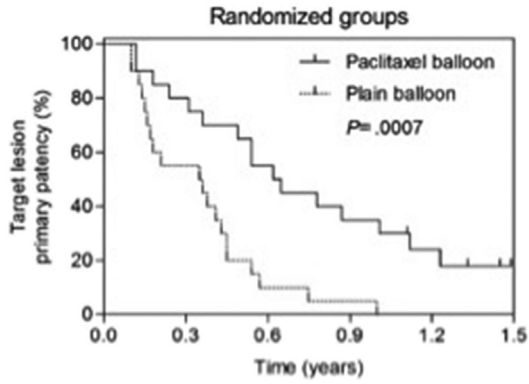

Fig. 3. Kaplan-Meier survival analysis of target lesion primary patency of all cases (those with AVF as well as grafts) randomized between drug-eluting balloon and brachio-axillary angioplasty treatment. (*From* Kitrou PM, Katsanos K, Spiliopoulos S, Karnabatidis D, Siablis D. Drug-eluting versus plain balloon angioplasty for the treatment of failing dialysis access: Final results and cost-effectiveness analysis from a prospective randomized controlled trial (NCT01174472). European Journal of Radiology. 2015;84(3):420; with permission.)

influences the rate of infection, with lower extremity AVG rates reported up to 41% [45,46].

An infected AVG requires a more complicated algorithm for treatment. *Staphylococcus aureus* (methicillin-susceptible and -resistant) is responsible for 70% of all access infections, whereas Gram-negative bacteria cause about 25% of infections [47]. In the presence of systemic sepsis or hemorrhage, urgent excision of the access is required. If a more indolent or localized infection is present, then complete or partial salvage of the access can be attempted. Usually a "jump graft" is performed around the infected portion of the graft. Once incisions are isolated, the infected remnant of the graft is excised. This technique is acceptable with the presence of less-virulent Gram-positive organisms [47]. More virulent infections (eg, methicillin-resistant *S aureus* and Gram-negative bacteria) are best treated with total or subtotal graft excision. Reconstruction of a brachial artery in the setting of gross infection can be technically difficult. Ligation of the brachial artery below the level of the profunda brachii is tolerated in most individuals and can be used when arterial reconstruction is either difficult or not feasible.

Dialysis-associated steal syndrome

Creation of an arteriovenous shunt causes an alteration of flow dynamics both systemically and locally. Although compensatory increases in inflow occur rapidly, sometimes as much as 20-fold, the perfusion bed distal to the arterial anastomosis has more limited adaptation [48]. The physiologic drop in pulse volume and pressure measurements in the extremity become pathologic in a proportion of patients, producing ischemic symptoms. The most common presentation involves:

- Numbness
- Coldness
- Paresthesias
- Pain in the digits and hand (for upper extremity access)

Acral ulceration and gangrene can occur in more advanced cases. The incidence of such complications ranges from 4% to 20%, and is more common in patients with diabetes mellitus and peripheral vascular disease [49,50]. Female gender and tobacco use may also increase dialysis-associated steal syndrome (DASS) risk [51]. Diminished digital plethysmography on preoperative studies can predict elevated risk of DASS, but no threshold value has been validated [52]. Distal brachial artery inflow seems to carry the highest risk of producing a steal syndrome. In most patients having prosthetic access, symptoms develop soon after the surgery. In patients with AVFs, symptoms may develop slowly and progress as the venous resistance diminishes with venous dilatation [53].

Diagnosis

DASS is a clinical diagnosis because it is a dynamic pathology and there is a significant variability of symptoms and examination findings depending on systemic hemodynamics. Low blood pressure states exacerbate steal symptoms, and use of the access for hemodialysis will typically worsen symptoms. Indeed, many patients *only* have steal symptoms while on the dialysis circuit.

It is important to discriminate ischemic symptoms from neuropathic symptoms. Hemodialysis patients, many of whom have preexisting neuropathies, are particularly prone to such symptoms. Most, but not all, patients with clinically significant steal will have absent radial and ulnar pulses to palpation. In many, compression of the access restores the pulse, and, when this causes immediate symptom relief, it is highly predictive of reversibility.

Diagnostic imaging

Arterial physiologic studies can be very helpful in the diagnosis and assessing of severity of steal syndrome [54]. A positive study will show markedly diminished digital pressures and pulse volume recordings at baseline, with significant normalization with access compression (Fig. 4). Some authors have suggested that flow reversal in the donor artery distal to the AVF is indicative of steal [55]. However flow reversal at this location is quite common in asymptomatic patients, and therefore very nonspecific in diagnosing DASS. Duplex calculated volume flow parameters can be helpful in identifying high flow fistulae, which may be more prone to producing steal symptoms. This parameter may also inform treatment options.

Arteriography is not particularly useful as a diagnostic modality but may be crucial to planning treatments. Inflow lesions of the subclavian and axillary artery may be identified in a small percentage of steal patients. Angiography is performed with a catheter placed proximal to the arterial anastomosis. In patients who experience ischemic steal, there will generally be no visualization of the distal vessels unless one performs digital compression of the access. In

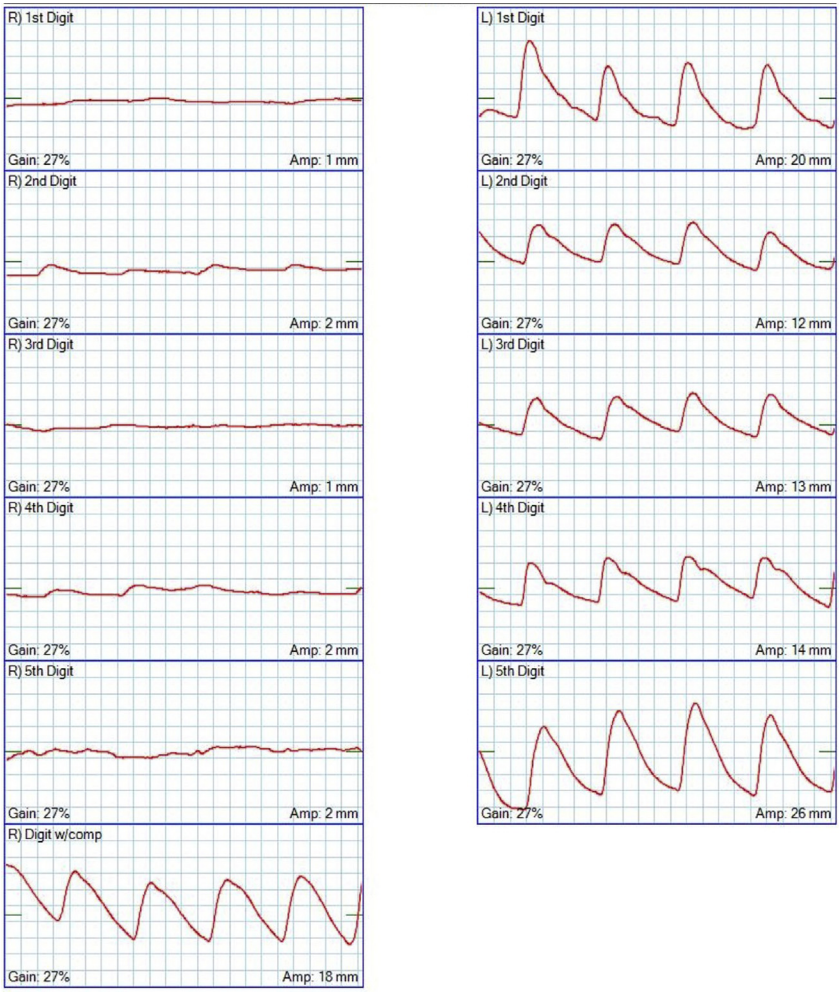

Fig. 4. This is an example of a steal study. The right digital waveforms are flat consistent with ischemia. This is compared with the left digits, which have normal waveforms. As seen in the last waveform on the right, the flow to the right digit augments with compression of the fistula/graft, indicative of steal.

our experience the most common arteriographic finding in patients with symptomatic steal is that of diffuse outflow disease affecting the radial, ulnar, and interosseous arteries in the forearm and hand. This anatomy is important to consider when surgical or endovascular intervention is recommended.

Interventions for steal

Ligation. Closing the access that caused ischemic steal syndrome is the simplest and most immediately effective mechanism to restore distal perfusion

to baseline. In patients who develop *severe* steal symptoms *immediately* after access creation, immediate ligation is appropriate to minimize postischemic neuropathy that can occur in this setting. Simple surgical ligation is the most common approach, but coil embolization can also be used. This has been reported for interruption of flow reversal in the radial artery, and is an attractive option in patients with normal arterial outflow and a complete palmar arch [56]. For AVGs, occlusion can sometimes be accomplished with prolonged digital or tourniquet compression.

Unfortunately, complete ligation leaves the patient without durable hemoaccess, and many have limited alternatives. If a patient has developed steal in one extremity, the likelihood of similar symptoms with contralateral access is high. However history of DASS on the ipsilateral side does not preclude more proximal graft placement [57].

Banding. Restricting rather than eliminating access flow is a logical option. Unfortunately the variability and complexity of the hemodynamic responses make the results of this approach somewhat unpredictable. Thrombosis is a common event in AVGs, and lowering flow in a prosthetic graft will likely increase this risk. High flow and autogenous accesses are better suited for banding.

Banding has been performed surgically with a variety of techniques to interpose a higher-resistance segment in the shunt circuit, usually at that arterial end to avoid recirculation and elevated pressure at puncture sites. A midaccess banding may be appropriate in patients with low-flow fistulae to allow an arterial cannula below the band to improve dialysis circuit flow. Endovascular banding has been described, but data are limited and we do not believe this provides a reliable and adjustable flow restriction [58]. Our technique for banding uses surgical clips to produce a smooth tapered narrowing of varying length and diameter.

We use either palmar arch Doppler flow signals or digital plethysmography cuffs to assess the hemodynamic effect of various degrees of plication. Restoration of biphasic Doppler flow with good pulsatile waveforms, while maintaining an adequate fistula flow as assessed by thrill palpation, is the goal. Once this has been accomplished, several mattress sutures are placed at the base of the clips, as it is not uncommon for clips to migrate off the fistula or graft over time (Fig. 5).

Distal revascularization with interval ligation. First reported by Schanzer in 1988, the DRIL procedure (distal revascularization with interval ligation) has come to be considered the most effective access-preserving procedure for dialysis-related steal syndrome. The technique involves placing a bypass originating at least 5 cm (ideally 10 cm) proximal to the arterial anastomosis, and ligating the artery just below the anastomosis (Fig. 6). The bypass is then performed distal to the ligation, ideally with saphenous vein conduit. Although reported results suggest a greater than 90% efficacy (compared with banding success in 70%–80%) the procedure involves significant morbidity and may not be suitable for many patients [59,60]. Ligation of the native artery in patients with

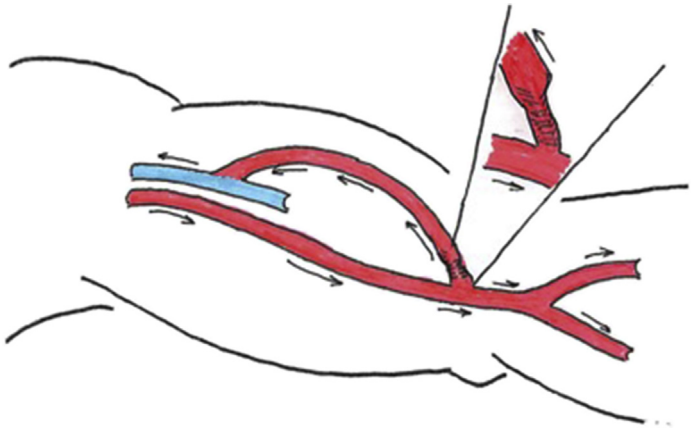

Fig. 5. Demonstrating banding of an arteriovenous fistula with surgical clips placed just distal to the anastomosis as well as mattress sutures to reinforce clips.

hand ischemia is unappealing to many, and some have suggested this can be omitted [59].

Revascularization using distal inflow. Distal brachial inflow for hemoaccess seems to carry the highest risk of producing steal symptoms, and an alternative to proximalization is to use a more distal inflow source, usually the radial artery (Fig. 7). First reported by Minion in 2005, there are only a few published reports involving a few dozen patients [61]. Results seemed comparable with DRIL in 1 comparative study [62]. Like banding, this is a flow restrictive approach, suggesting that results should not significantly differ [61,62].

Proximalization of arterial inflow. First reported by Zanow in 2006, this technique involves effectively re-siting the proximal anastomosis by constructing

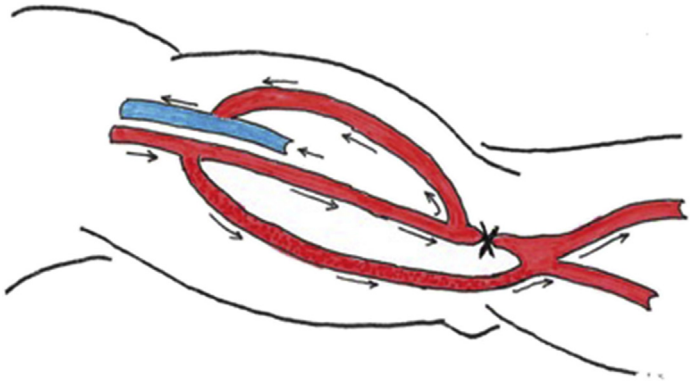

Fig. 6. DRIL procedure with ligation of the artery just distal to the anastomosis. Bypass is created 5 to 10 cm proximal to the anastomosis to beyond the ligated artery.

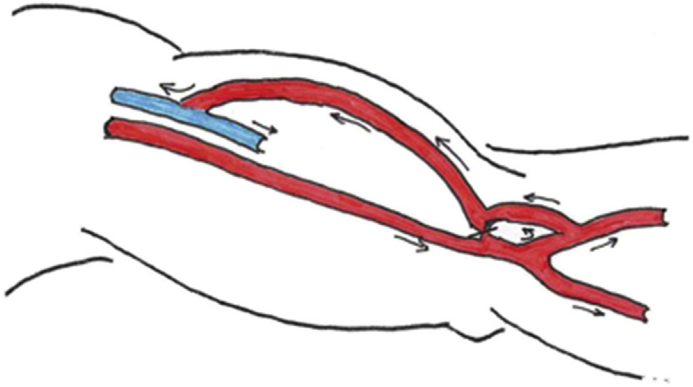

Fig. 7. Revascularization using distal inflow procedure showing ligation of the anastomosis and revascularization by using more distal inflow, generally the radial artery.

an interposition graft from the axillary artery to the arterial aspect of the fistula, ligating the fistula anastomosis rather than the artery (Fig. 8) [63]. There are only a few reports published, but results seem to be similar to those achieved with DRIL. This may be a more appealing option in patients with low-flow prosthetic grafts.

Dialysis-associated steal syndrome treatment algorithm. Our approach has been to use banding as the initial approach in patients with high flow accesses and those with prosthetic grafts, unless there is profound hand ischemia or tissue loss. Banding is a simple and minimally morbid procedure, and in the one-third of patients in whom it is ineffective, more aggressive options can be pursued. For patients with tissue loss, DRIL would be preferred in those with autogenous access and suitable saphenous conduit. We prefer proximalization in patients with prosthetic grafts and in low-flow situations, and consider

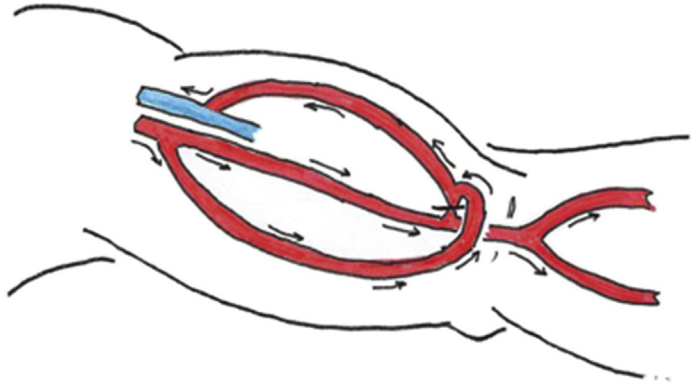

Fig. 8. Proximalization of arterial inflow, with ligation of the anastomosis and creating a bypass from the axillary artery to the most distal aspect of the fistula.

revascularization using distal inflow an alternative method of banding [49]. Fig. 9 depicts a systematic approach to the diagnosis and management of DASS. Whatever intervention is elected should be undertaken with the appreciation that patients with DASS have significantly all-cause mortality risk compared with other dialysis patients, 28% and 79% at 1 and 5 years, respectively in 1 review [60].

Pseudoaneurysm and aneurysm

Aneurysm and pseudoaneurysm (PA) formation in hemodialysis access is common, requiring intervention in 2% to 10% of patients [64]. PAs are false aneurysms that do not contain all the layers of the vessel wall and typically arise from AVGs. In contrast, aneurysms typically arising from AVFs, are more often true aneurysms that contain all the layers of the vessel wall. Although PAs and aneurysms can be unsightly, there are few absolute indications for treatment: bleeding or impending rupture. Soft indications for aneurysm repair are pain, compressive neuropathies, cosmetic, or cannulation difficulty.

PAs and aneurysms arising from hemoaccess can be treated by open or endovascular approach [64,65]. Open techniques include aneurysmorrhaphy, patch angioplasty, and interposition grafting [65,66]. For AVFs we try to keep the access autogenous. For multiple aneurysms, staged revision may be used to preserve accessibility and avoid TCD. Open revision involves an

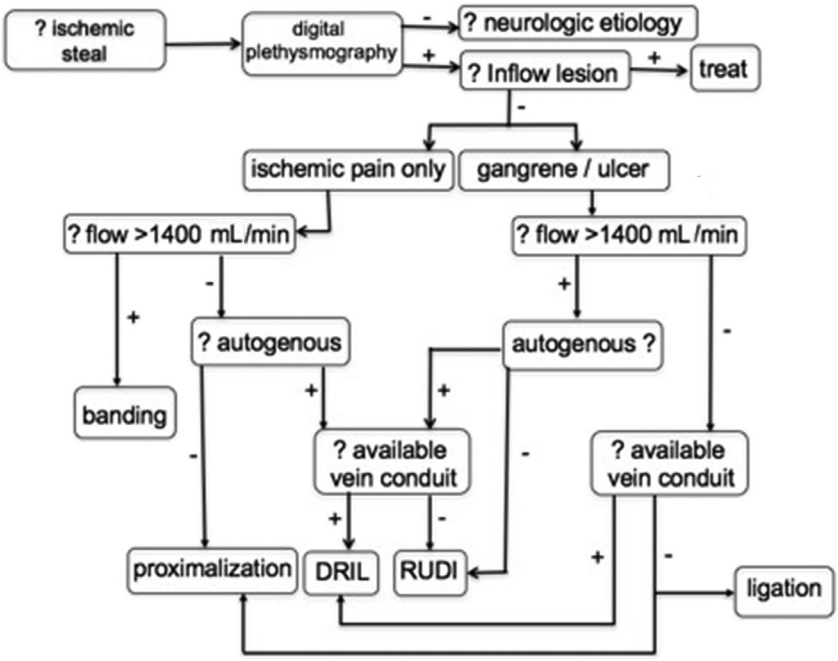

Fig. 9. Treatment algorithm for patients with steal.

elliptical incision over the aneurysm to remove the compromised portion of skin (Fig. 10). Mural thrombus is removed if present, and redundant tissue is excised. The aneurysmorrhaphy is performed by plicating healthy vessel wall over an 18F catheter as a mandrill. Tortuousity is common with AVF aneurysms, often allowing excision and end-to-end anastomosis. The revised portion can be accessed after 4 weeks.

Endovascular treatment with stent grafting is appropriate if the aneurysm is localized and access diameter normal adjacent to it [64,67]. We have used this technique more often with PAs arising from AVGs. Stent grafts can be technically difficult to cannulate, especially through a thrombosed PA/aneurysm sac, so it is avoided when cannulation length is limited.

Erosion/bleeding

Persistent bleeding after access cannulation suggests venous hypertension, usually secondary to a venous outflow stenosis. The hemoaccess is best evaluated with either duplex ultrasonography or fistulogram followed by treatment with balloon angioplasty and/or stent [68]. Erosions can result from repetitive puncture, thinned skin cover, inflammation, and infection [69]. Use of a "ladder technique" to cannulate the access may help prevent these lesions. Once established, treatment of infection, local excision of compromised skin and eschar, or stent graft exclusion, are all acceptable measures for treatment. Fatal hemorrhage can occur when an erosion bleeds, and it is important to treat these lesions in a timely fashion when they present [70]. Scabbing is very common with access cannulation, but if a scab larger than 5 mm persists, and the surrounding skin is not mobile over the fistula, urgent repair is indicated (Fig. 11).

Diabetic neuropathy and uremic neuropathy are both systemic conditions that affect a significant percentage of hemodialysis patients. Diabetic neuropathy is caused from large fiber demyelination leading to clinical manifestations of numbness, paresthesia, and pain. This most commonly occurs in the lower extremities, but can also occur in the upper extremities [71]. Uremic neuropathy is secondary to axonal degeneration with secondary segmental demyelination. It affects 50% to 70% of patients on hemodialysis and is more prevalent in men than women. Clinical symptoms include loss of sensation/vibration and loss of

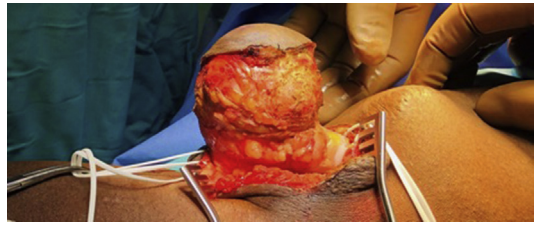

Fig. 10. Aneurysm of AVF dissected circumferentially with proximal and distal control, overlying ellipsed soft tissue.

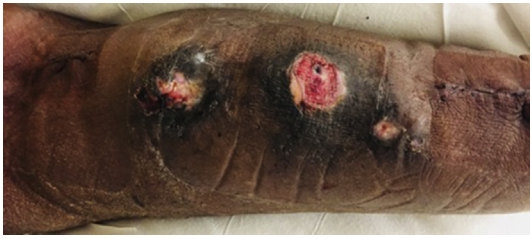

Fig. 11. AVF with overlying soft tissue erosions.

deep tendon reflex [72]. These neuropathies are not caused by access creation in hemodialysis patients, thus it is important to differentiate these neuropathies from those that are caused by the access itself.

Compressive neuropathies secondary to access creation include carpal tunnel syndrome (CTS), Guyton tunnel syndrome, and sometimes cutaneous nerve compression from the access itself. CTS is the most common compressive neuropathy seen and occurs 10 times more frequently in hemodialysis patients [73]. Two theories for increased CTS in hemodialysis patients exist. The first is venous hypertension and congestion causing edema and with median nerve compression in the tunnel [74]. The second is chronic irritation to the carpal tunnel ligament secondary to amyloid deposition [75]. CTS is clinically diagnosed with weakness, pain, and paresthesias in the median nerve distribution, confirmed by electromyogram and treated with decompression of the carpal tunnel. Other compressive neuropathies are treated in a similar fashion with surgical decompression of the affected nerve. These must be differentiated from ischemic symptoms.

An unpredictable and much less common condition, ischemic monomyelic neuropathy (IMN), occurs in less than 0.5% of patients after access creation. This can result in significant and irreversible deficits, especially if there is a delay in diagnosis. IMN is observed most often in brachial access creation, typically in patients with diabetes. It is theorized that access creation results in decreased perfusion to already compromised perfusion of peripheral nerves, at a microvascular level. It is different than ischemic steal syndrome, because, in IMN, the hand remains warm and has distal pulses by palpation or Doppler examination. Pain, weakness, and hyperesthesia is out of proportion to physical findings, and usually is noted within hours of access creation. This can affect one or all of the ulnar, radial, or median nerves. Many believe treatment should be urgent ligation of the access, as symptoms rarely reverse without eliminating the shunt. Even with urgent ligation, permanent deficits may persist [76].

High flow states

High-output congestive heart failure (CHF) may occur in a high flow access. This is diagnosed clinically with the Nicoladoni-Branham sign, where

temporary occlusion of the access causes slowing of the heart rate. Flow rates causing CHF are typically greater than 2.5 L/min and divert 25% or more of cardiac output. High flow states causing symptoms are usually seen in brachial-based access. Banding or ligation may be used for surgical correction [77,78].

SUMMARY

The demand for hemodialysis access is increasing and many challenges remain. Improvements in prevalence of autogenous access has not reduced the need for improvements in maintenance and treatment of complications of hemoaccess. The usefulness of endovascular technologies has increased, but surgical therapies will remain important for the foreseeable future.

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