Successful Angioaccess

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Surgery for hemodialysis (HD) access is the most commonly performed vascular surgical operation in the United States, predominantly because of a steady increase in the prevalence of end-stage renal disease (ESRD). Despite a concomitant increase in the mean age of these patients and more coexisting morbidities, advances in the management of renal failure and dialysis have allowed for a longer survival among patients on HD. The Achilles heel for these patients remains vascular access, however, with poor long-term patency rates resulting in multiple interventions for thrombosis and maintenance, and, in many patients, the eventual need for lifelong catheter placement. Access failure is the second leading cause of hospitalization among patients who have ESRD, and the annual cost of access maintenance is estimated to be $1 billion in the United States [1].

Multiple studies have confirmed the improved patency rate and lower infection rates for native arteriovenous fistulae (AVF) compared with prosthetic arteriovenous grafts (AVG). Although approximately 60% to 90% of nonautogenous grafts are functional at 1 year, the patency falls to 40% to 60% at 3 years [2]. Despite inferior patency rates, prosthetic grafts continue to be more common than native fistulae in the United States, accounting for 65% of all access procedures. In contrast, data from Canada and Europe demonstrate greater use of autogenous fistulae in those countries, with prosthetic grafts accounting for less than 35% of all access procedures in Canada and 10% in Europe [3].

In an effort to promote more standardized practice patterns and greater success with autogenous access placement, the National Kidney Foundation
introduced the Dialysis Outcome Quality Initiative (DOQI) [4]. In the past these guidelines set the goal of greater than 50% of all dialysis access being autogenous. The most recent recommendation is a prevalence of AVF of greater 65% by 2009 [5]. This performance metric is a goal that the Center for Medicare Services expects for reimbursement. Although it is a useful guideline, it does not take into account variations in patient populations. Many patients are not referred to a surgeon per DOQI guidelines when their creatinine clearance is less than 25 mL/min for access consideration before initiation of HD. Many patients present with a tunneled catheter in place that is malfunctioning and may not have time to wait for an autogenous access to mature. Usually it is between these two extremes that we, as surgeons, are asked to see these patients. Using a “fistula first” practice results in better long-term patency but must be tempered with the needs of the specific patient in question.

In formulating a strategy for successful dialysis access a comprehensive approach should be undertaken. This approach involves understanding this patient population and working with the nephrologist to create an environment that is beneficial to the patient. Surgeons who perform these procedures understand that the challenge is not the simple technical process of creating an AVF, but understanding the potential pitfalls that can be associated with access. The preoperative planning, as with any surgical procedure, is the most important aspect, followed by the postoperative maintenance of the access.

**Preoperative strategy**

The planning for HD access should ideally allow for adequate maturation time for an AVF, which is between 6 and 8 weeks (up to 12 weeks). This timing would optimize the use of autogenous access; however, this is often not possible and the patient requires access sooner. Every surgeon should adopt a standard algorithm for HD access. Our algorithm of access is as follows: nondominant upper extremity, the most distal site first, and autogenous access before prosthetic. Within every algorithm there exist variations. For example, women are more likely to undergo insertion of prosthetic grafts than men and have higher failure rates of AVF, which is likely a reflection of the larger caliber of superficial arm veins in men [6]. Maintaining a standard practice has been shown to increase the percentage of autogenous access, however [7].

History should include any prior access procedures or recent intravenous lines, particularly central lines, because subclavian lines are associated with an extremely high rate of stenosis [8]. Physical examination should focus on bilateral upper extremity blood pressure to detect a potential subclavian artery stenosis and palpation of the brachial and radial pulses. An Allen test should be performed to ensure there is adequate radial and ulnar flow to the hand (Fig. 1).
Ultrasound may be incorporated into preoperative planning, particularly for autogenous access placement. Duplex ultrasound (DU) has been used for preoperative planning in dialysis access, and studies have shown a proven benefit of ultrasound in predicting success in patients who have undergone a preoperative ultrasound [9]. Robbin and colleagues [10] noted an increase in autogenous arteriovenous access creation from 32% to 58% after a preoperative DU program was started. With preoperative ultrasonography, Silva and colleagues [11] were also able to demonstrate an increase in autogenous access placement from 14% to 63% and a decrease in failure of autogenous access from 38% to 8.3%. In that study, veins greater than 2.5 mm were required for autogenous access placement and greater than 4 mm for non-autogenous placement. Using the criteria of a 2-mm vein at the wrist and greater than 3 mm in the upper arm, Ascher and colleagues [12] reported a similar increase in autogenous access placement with preoperative DU.

Most preoperative ultrasound procedures can be performed in an office or vascular laboratory setting. The forearm venous network is superficial and easily imaged (Fig. 2). Superficial veins can be visualized longitudinally and in cross section. If these veins are compressible, greater than 2.5 mm, and patent throughout their course, then an autogenous access can likely be performed. Mendes and colleagues [13] studied the cephalic vein preoperatively with DU to determine whether a minimal cephalic vein size in the forearm could predict successful wrist autogenous access. They noted that patients who had a cephalic vein size of 2.0 mm or smaller were less likely to have a successful wrist autogenous access than if the cephalic vein was greater than 2.0 mm [13]. If the patient’s history suggests previous central venous lines or arm swelling, the deep veins, such as the
axillary and distal subclavian, can also be interrogated (Fig. 3). The bony clavicle limits accurate assessment at the mid to proximal subclavian level. Color flow DU may also be used to assess the arterial inflow. Starting at the wrist the radial artery can be identified and followed proximally to the brachial artery. Using color flow in the longitudinal view, occlusive arterial disease can be identified. Unobstructed arterial inflow of 2.0 mm has been used as a predictor of success [14,15].

Arteriography and venography may be incorporated into the preoperative planning of patients. Iodinated contrast agents are nephrotoxic and carbon dioxide or gadolinium should be used instead in patients who have residual renal function. Arteriography is usually recommended in patients who have evidence of significant inflow disease as directed by physical examination or ultrasonography. If a short-segment subclavian stenosis is identified, it may be treated with angioplasty and stenting. Contrast venography should be incorporated in the preoperative planning in patients who have poor veins noted on duplex or if there is a history of prior central venous access, particularly in the subclavian vein [16,17].

After adequate preoperative planning the choice of access can be determined and can either be autogenous or prosthetic. Generally in our practice, when patients are referred relatively early we aggressively attempt
autogenous access and attempt radiocephalic access with a smaller cephalic vein (ie, 1.6 mm). The reason for this is that it is a relatively benign procedure and potentially has the benefit of increasing the caliber of the more proximal veins if it does not mature itself.

Autogenous access

The first choice of autogenous access is the radial artery to cephalic vein fistula. First described in 1966, it is the most well-known autogenous access performed and is also referred to as the Brescia-Cimino fistula or the wrist fistula [18]. It is performed in various ways but the most common involves an end of the cephalic vein to the side of the radial artery. This procedure can be accomplished with one or two incisions. In general the vein is mobilized near the wrist, an adequate segment of the radial artery is identified, and the anastomosis is performed with 6-0 polypropylene suture in a running style (Fig. 4). This fistula is then given 6 to 8 weeks to mature before accessing it for HD. Many times this AVF is slow to mature because large tributaries in the forearm may shunt flow away from the cephalic vein.

Fig. 3. Ultrasound of proximal subclavian vein.

Fig. 4. Radiocephalic fistula.
Identification of these tributaries by physical examination, ultrasonography, or fistulogram and ligation usually allows the cephalic vein to subsequently mature.

Another variation of the Brescia-Cimino fistula is the “snuffbox” fistula [19]. It is an anastomosis between the distal cephalic vein and the thenar branch of the radial artery that can be found in the anatomic snuffbox of the hand (Fig. 5). It can generally be performed through one incision over the snuffbox and is the most distal autogenous fistula. It is an end of the cephalic vein to the side of the thenar branch of the radial artery anastomosis. It may require finer suture (7-0) because the vessels are smaller. This fistula affords the luxury of an extremely small incision and the potential of increasing the size of the more distal veins.

Another forearm autogenous access is the radial artery to forearm basilic vein transposition [20]. It involves an incision along the forearm portion of
the basilic vein and mobilization toward the antecubital fossa. The radial artery is then exposed and a subcutaneous tunnel is created to allow the basilic vein to be transposed toward the proximal radial artery (Fig. 6). Using this fistula still preserves the upper arm access if it does not mature.

The brachial artery to cephalic vein fistula is the next higher-level autogenous fistula. It involves an anastomosis between the brachial artery and cephalic vein in the antecubital fossa. It is generally performed in an end of cephalic vein to side of brachial artery configuration. It has excellent flow

![Diagram](image_url)

Fig. 6. Forearm basilic vein transposition. (From Hallett JW Jr, Mills JL, Earnshaw JJ, et al, editors. Comprehensive vascular and endovascular surgery. St. Louis: Mosby; 2004; with permission.)
and maturation rates but has been associated with higher rates of “steal” phenomenon [21]. It also eliminates the forearm for consideration of future access.

The brachial artery to basilic vein fistula is the last autogenous conduit in the upper arm. The operation is done under general anesthesia; it requires more extensive dissection because the basilic vein is deeper in the upper arm. The preoperatively marked basilic vein requires transposition to a more superficial location so it can be accessed. Results have varied with some reporting excellent patency and others reporting less favorable results [22,23].

Prosthetic access

AVGs are associated with poorer patency than an AVF; however, they do have the advantage of easier cannulation and a much shorter time to maturation requiring only 14 days before access can be achieved. Generally these grafts are made from expanded polytetrafluoroethylene (PTFE) and come in a variety of sizes. Most grafts are 6 mm but there are also tapered grafts with a 4-mm arterial end and a 7-mm venous end. The principle cause of failure in an AVG (80%) is neointimal hyperplasia at the venous anastomosis. Compared with AVF, however, the secondary patency rates may be higher because salvage procedures are more readily performed in prosthetic grafts.

The most distal forearm graft is the straight radial artery to cephalic or antecubital vein graft. Another forearm graft is the brachial to cephalic or basilic vein loop graft. These grafts are performed with end of graft to side of artery and vein anastomosis with 6-0 polypropylene sutures or CV6 Gore-Tex PTFE suture. Again these AVGs provide relatively simple access and may be used in the face of disadvantaged forearm veins (Figs. 7 and 8).

The next level of prosthetic is the brachial artery to axillary vein graft that provides the last level of access in the upper arm. It can be performed after a failed brachial-basilic AVF as long as the axillary vein is patent and it is an end of graft to side of artery and vein anastomosis. Other potential and less often used sites are the cross-chest axillary artery to axillary vein graft and lower extremity thigh loop grafts, which are not discussed here.

Complications

Failure of maturation of arteriovenous fistulae

AVFs may take up to 12 weeks to mature but in an access such as the radial-cephalic fistula the cause may be multiple tributaries of the cephalic vein that should be ligated. This ligation can be accomplished by identifying prominent vessels on physical examination, using duplex ultrasonography to mark these, or using fistulograms to identify and ligate these branches. Even if the radiocephalic AVF does not mature properly it may promote
the enlargement of the more prominent veins to allow for a more durable proximal upper extremity fistula.

The failing or thrombosed access

Often a patient is referred back to the surgeon with a question of a poorly functioning AVF and AVG. Unlike AVGs, an AVF can remain patent with
minimal flow, therefore Doppler or duplex interrogation of a suspected thrombosed AVF should be performed to confirm or exclude the diagnosis. High recirculation times, elevated venous pressures, and inability to achieve adequate urea clearance are signs of a venous outflow obstruction. The treatment of a thrombosed AVG has been described in several series and can range from endovascular thrombolysis to surgical thrombectomy with
patch angioplasty of the venous outflow. Rescue of a failing or thrombosed AVF has been mixed with AVG studies but in general they are not as easily salvaged. These results are similar to a thrombosed autogenous lower extremity bypass [24,25].

Endovascular therapy involves assessing the venous outflow and dilating any stenosis noted along with a central venogram to rule out a central vein stenosis. One technique that is used for thrombosed AVGs is the “lyse and wait” technique. This technique involves cannulating the AVG with an 18-guage Angiocath and instilling 3 mg of tissue plasminogen factor (tPA) and 3000 units of heparin while compressing the arterial and venous ends of the graft. After waiting anywhere from 30 minutes to 2 hours a venogram is performed. Any outflow stenosis is angioplastied. Next a sheath, directed toward the arterial end, is placed and a Fogarty embolectomy catheter is used to dislodge the arterial plug. This technique is useful and can be repeated without having to perform surgical correction or revision and unidentified lesions can be found and treated from the venous outflow tract to the central veins [26].

Surgical thrombectomy is fairly standard with the incision placed over the venous outflow and the use of a Fogarty catheter to remove the arterial thrombus. The venous end then has a PTFE or Dacron patch placed. Completion venography should be performed to visualize the venous outflow and identify lesions that may require further treatment.

Venous hypertension

Mild arm swelling is a common finding in these patients; however, this can be a more devastating complication with some patients having severe swelling. This complication is usually the result of outflow vein or subclavian or central vein stenosis or occlusion. This problem can be treated by angioplasty of the central vein with good initial results; however, these are prone to recurrence and the need for reintervention [27]. If swelling is not controlled and the patient begins to have signs of venous ulceration, then ligation of the AVF or AVG is warranted.

Infection

AVGs are more prone to infection, particularly with Staphylococcus aureus. The very nature of a superficial graft, with repeated punctures in perhaps not the most sterile of environments, and the impaired immunity of these dialysis patients all play a role [28]. If a graft is suspected of infection without any signs of exposed graft than a trial of antibiotics should be initiated. If there is a tract or exposed graft then excision of this portion of the graft should be performed with removal of all of the unincorporated graft. If it is a short section, using another graft tunneled in a clean plane between the uninfected incorporated portions of the graft can be performed (Fig. 9) [29].
Pseudoaneurysm

Pseudoaneurysm (PSA) formation within an AVF does not necessarily imply infection, because repeated cannulation can cause this problem. A PSA of an AVG may be associated with infection because the scar tissue around the graft limits the formation of a PSA. If a PSA continues to enlarge and the overlying skin is threatened, it should be repaired. This repair can be done with segmental excision and bypass or with emerging endovascular techniques with a covered stent. There are case reports describing this technique and the results have been variable [30].

Steal

Creation of either an AVF or AVG may predispose a patient to ischemic steal symptoms. This phenomenon may manifest as cool digits or profound ischemic changes, such as tissue loss. A patient develops steal because of the reduced pressure just proximal to the fistula secondary to the large capacitance of the venous outflow and blood preferentially flowing in this direction. Generally this can be managed with a trial of observation if the symptoms are mild. To diagnose steal various techniques from physical examination to arteriography are required. If compression of the AVF results in restoration of a palpable radial pulse and resolution of symptoms, a confirmatory arteriogram to rule out an inflow stenosis or more distal native arterial stenosis is required. The brachial artery to cephalic vein fistula is the fistula most commonly associated with this complication. The treatment can involve revision of the anastomosis or operative banding, which has not been too successful. Another procedure that involves preservation of the access site is the distal revascularization with interval ligation (DRIL) procedure. Originally described by Shanzer and colleagues [31] it involves ligating the artery distal to the fistula and than constructing a bypass 3 to 5 cm above the AVF anastomosis (above the reduced pressure area) to the distal native artery (Fig. 10). The DRIL procedure is extremely effective.
and should be used in patients who have a functioning native AVF and limited access availability. The decision to ligate an axial artery for preservation of a prosthetic fistula needs to be weighed carefully with consideration given to the lifespan of a prosthetic graft. Another technique is proximalization of the arterial anastomosis, which has recently been described with good results by Zanow and colleagues [32]. This technique involves dissecting the arterialized fistula vein near the AVF anastomosis and ligating and dividing it. The inflow artery (more proximal brachial or axillary artery) is then dissected and a 4-mm expanded PTFE graft is used between this artery and the efferent vein to construct a bypass (Fig. 11). In their series 84% of access-related ischemic symptoms resolved. The increasing use of endovascular procedures has led to novel approaches to difficulties with HD access. Recently

Fig. 10. DRIL procedure. (From Hallett JW Jr, Mills JL, Earnshaw JJ, et al, editors. Comprehensive vascular and endovascular surgery. St. Louis: Mosby; 2004; with permission.)
steal has been managed using minimally invasive techniques whereby the venous end of the AV anastomosis is accessed with a wire and a 4-mm angioplasty balloon inflated. A small incision is made over the vein and a single Prolene suture tied around the vein with the balloon inflated. The vein is thus banded with exacting fashion to relieve steal. With this technique, the authors have noted a 94% technical success rate for treating patients who have steal, thus avoiding an extensive DRIL procedure [33].

Summary

Creating effective dialysis access requires a comprehensive plan formulated between the nephrologist, the surgeon, and the patient. In this setting, HD access is the patient’s lifeline and maintaining it requires a plan to deal with the aforementioned complications and sometimes low patency rates. To optimize success, the most important aspect, as with any other surgical procedure, is the preoperative planning. Understanding and dealing with the potential complications allows the surgeon the ability to optimize the practice of HD access.

References