Surgical Approach to Hemodialysis Access

Jarrad W. Rowse, MD¹ Lee Kirksey, MD, MBA¹

¹ Department of Vascular Surgery, Heart and Vascular Institute, Cleveland Clinic, Cleveland, Ohio

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Address for correspondence Jarrad W. Rowse, MD, Department of Vascular Surgery, Heart and Vascular Institute, Cleveland Clinic, Code H32, 9500 Euclid Avenue, Cleveland, OH 44195 (e-mail: rowsej@ccf.org).

Abstract

Keywords

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- surgery
- interventional radiology
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With the increasing incidence of end-stage renal disease, hemodialysis vascular access presents an ongoing struggle, and a multidisciplinary approach must be considered to provide long-term durable access for patients on chronic hemodialysis. Surgeons must be very thoughtful in planning the steps of access for these patients and consider fistula first and catheter last, without forgetting that prosthetic grafts may be a legitimate first option for patients. This article provides a review of surgical management of dialysis access, including primary access options and follow-up of this difficult patient population.

Objectives: Upon completion of this article, the reader will be able to describe the general tenets of surgical planning when evaluating a patient for hemodialysis vascular access.

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Vascular access remains a significant challenge for patients on chronic hemodialysis (HD) and often requires creative thinking to preserve and construct durable long-term access. Routes for HD vascular access include (1) tunneled dialysis catheter (TDC), (2) prosthetic bridge graft (PBG), and (3) arteriovenous fistula (AVF). Despite efforts of the *National Kidney Foundation Disease Outcomes Quality Initiative* (NKF DOQI) and the *Fistula First Breakthrough Initiative* (FFBI) encouraging providers to identify and refer patients earlier for permanent dialysis access creation,^{1,2}

nationally 60% of incident patients are initiated on HD via a TDC.³

In 2006, the FFBI, based on the early success of the program's goal to achieve higher autologous fistula rates, modified the prevalent AVF goal to 66%. Additionally, FFBI set forth a goal of reducing national rates of long-term TDC (i.e., not as a bridge) to less than 10%.² Unfortunately, that lofty program goal has not been reached even though it has been well established that TDCs have an increase in all-cause mortality.⁴ Recently, the program's name has been modified to *Fistula First/Catheter Last*,^{2,4} with a continued emphasis on placement of autogenous fistulas; however, there is increasing acceptance that prosthetic grafts have a place in certain patient groups where AVFs are not an option.^{5,6} AVFs have higher primary patency,⁷ lower risk of infection, higher durability, lower mortality,^{8–10} and fewer required interventions⁷ when compared with prosthetic grafts and TDCs. However, AVFs have a high rate of nonmaturation (20–50%),^{4,11–13} which likely accounts for the fact that at 6 months after initiating HD, 55% of patients continue to be dialyzed with a TDC.^{1–3,14–16} Additionally, contemporary literature suggests that secondary patency for PBGs is similar to that of AVFs. While AVFs continue to remain the gold standard for vascular access, HD access remains an ongoing challenge for surgeons and patients alike.^{7,8,14–17}

Initial Patient Evaluation

Evaluation of a patient for permanent HD access begins first with a thorough history and physical exam, with imaging as indicated. The history should begin with information on hand dominance, previous vascular access (central venous catheters, peripherally inserted central catheter, pacemaker, defibrillator), upper and lower extremity venous thrombosis, hand ischemia, and pulmonary hypertension. The upper extremities should be examined with an upper arm tourniquet in place, paying particular attention to the frequently neglected forearm basilic vein, prominent cutaneous chest wall veins, brachial pressure comparison from arm to arm, the presence and quality of radial and ulnar pulses, and arm circumference. Large arm circumference may represent a challenge to transposed reconstruction in the upper arm and frequently necessitates transposition or superficialization of veins in the forearm.

Duplex venous ultrasound (DUS) evaluation of the arms and legs, particularly when performed by the surgeon, provides insight into aberrant branching patterns that dictate incision placement. A vein diameter of 3.0 mm is preferred; however, the absence of phlebotic or calcific changes is equally important and a 2.5-mm nondiseased vessel may be useable.¹⁸ Arterial mapping with DUS evaluation is used to quantify vessel diameter and the absence of calcification. Note the presence of high brachial artery bifurcations, which are associated with fistula nonmaturation and graft occlusion.^{19,20} The role of corresponding arterial dilation necessary to cause vein maturation is underappreciated and likely explains the lower rate of maturation in diabetics with fibrocalcific vascular changes. Pulse volume recordings (PVRs) of the arms or legs may be required in the face of absent pulses, which may be due to noncompressible diabetic calcinosis. Given a low rate of stenosis in noninstrumented central veins, venograms should be used only selectively in primary vascular access creation, except in patients with stigmata of central venous stenosis. It remains controversial whether to intervene prospectively/prophylactically on central vein stenoses or only if symptoms develop following access creation. In patients with chronic kidney stage IV/V disease, using carbon dioxide as a contrast agent with or without a small amount of contrast can allow the central veins to be evaluated for those patients in whom renal replacement therapy has not yet been initiated.

For secondary access creation in surgical fields that have previously been operated upon, venography is routinely performed to complement duplex vein mapping, as DUS is less reliable as a standalone modality to evaluate vessel continuity. In planning lower extremity access, there should be a low threshold for arteriography to evaluate diabetics, particularly if any physical exam pulse abnormality exists. Otherwise, normal PVRs are requisite to document normal pedal perfusion and should be complemented with toe pressure measurements to assess microvascular pedal level disease. Secondary vascular access evaluation of the lower extremity veins may require computed tomography or magnetic resonance venography of the ilio caval segments, particularly if there is a history of prior lower extremity catheter

usage. The authors prefer to preserve the lower extremity veins with the placement of a translumbar catheter, if possible and clinically appropriate.

Vascular Access Clinical Principles and Selection of Primary Access Site

Contrary to the normal dictum, patency of a vascular access is not the ultimate clinical parameter of success. Anatomic success relies on the “rule of 6s”: 6 mm vein diameter, <6 mm below skin, 600 mL/minute flow, and 6 cm length of cannulatable vessel.²¹ The best conduit is superficial, easily identified, straight, and of large caliber. The ultimate determinant of vascular access success is whether the conduit can be cannulated (14–16 gauge, 3/5–1.0 in needles). The very nature of cannulation introduces a level of unpredictability that is predicated heavily upon the individual patient and variable skill level of the cannulating technician.⁵

Based on the overarching theme of Fistula First, the most distal autogenous vascular access option is sought.²¹ A radial artery to cephalic vein (Brescia Cimino) fistula has a high rate of nonmaturation (approaching 50%) especially in patients of advanced age; these fistulas, however, can afford long-term reliable access in younger patients.²² A basilic vein to ulnar artery fistula is an often-neglected option, particularly as the vein is frequently preserved and free of venipuncture trauma. However, it must be secondarily transposed to the volar surface in a staged fashion for patient comfort during dialysis.

An important and frequently unappreciated anatomic consideration is that any AVF may require transposition if it matures sufficiently, but is not able to be visualized for cannulation. Most frequently in normally visible superficial veins, this lack of visibility is secondary to obese patient body habitus. Veins that will mature should show 30 to 50% dilatation at 4 weeks postoperatively, and surveillance vascular access DUS can be used to evaluate for these changes. If clinical/ultrasonographic findings of dilatation and increased flow are not noted, the fistula should be examined carefully for para-anastomotic flow, limiting inflow lesions (soft, easily compressed fistula with reduced thrill), or competing accessory veins (although the contribution of accessory veins to nonmaturation is not fully agreed upon). In the absence of correctable lesions within the fistula, the vascular access team should have a clear understanding of the threshold and time frame used to abandon a physiologically optimized but nonmaturing fistula and proceed to a new site. Poor communication and delayed decision making contribute to avoidable and prolonged use of TDC, which can lead to increased risk of systemic infection, venous stenosis, and a decreased life expectancy of the dialysis access.^{2,8}

When forearm autogenous access is not available, following FFBI the upper arm should be evaluated for autogenous reconstruction (i.e., cephalic, basilic, or brachial veins). A two-stage approach to the upper arm fistula construction is advocated due to increased patency rates, with the first stage being primary artery to vein anastomosis through a local incision.²³ Several factors explain the higher rate of nonmaturation with one stage including warm ischemia to the

conduit with dissection from its native vascular bed, blood vessel trauma, and subsequent fibrosis in the tunneling/transposition step. The conduits produced by the two-stage approach are uniformly larger and are more easily transposed. Reduced rates of infiltration translate into more durable conduits. Traditionally, brachial artery to cephalic vein AVFs do not require a two-stage approach; however, with the increasing prevalence of obesity in the general population, it is now common to transpose a mature cephalic vein as a second-stage procedure simply for identification in cannulation. Continued evidence demonstrates that a transposed upper arm fistula requires fewer interventions to maintain patency, fewer revisions, and decreased risk of infection when compared with upper arm prosthetic grafts.^{7,23,24}

Of note, in the era of FFBI, the role of the forearm PBG remains to be determined. Proponents of the forearm PBG approach suggest that it may enhance maturation of upper arm veins, leading to secondary upper AVF creation; opponents note high rates of subsequent fibrosis of the recipient antecubital and outflow basilic/brachial/cephalic venous system when a PBG is created initially.

For the patient who has limited vein options due to vessel size with regard to the conventional basilic and cephalic approach, a conditioning brachial artery to brachial vein fistula can be performed. The brachial vein will either mature along the entire upper arm length and can then be transposed or it will mature at the outflow brachial/axillary vein segment, which will yield a much more durable patency when a bridge graft is constructed at a second stage.²⁵

When options in both arms in the infraclavicular location are exhausted, the ipsilateral axillary artery–axillary vein or chest wall “chandelier” represents a novel and neglected option. Because of the high flow arterial and venous flow properties, these constructions are durable. The deleterious impact of this proximal reconstruction on heart disease and pulmonary hypertension should be carefully considered. Because “proximalization” is a treatment for steal syndrome, the development of regional hand ischemia is low.²⁶

Comparison of Nontransposed Forearm and Upper Arm Fistulas

The reported literature is evolving to clarify the patency data with novel fistula configurations. It is clear that the gold standard for vascular access durability is the Brescia Cimino fistula. After maturation, especially in young patients, this reconstruction may yield decades of function. The same cannot be expected of transposed reconstructions, which ultimately develop swing point (the anatomic area at the upper arm segment of vein where it transitions to the in situ position) lesions likely caused by flow turbulence and mechanical strain. In fact, although much of the literature suggests that the primary patency of the autogenous fistula is significantly better than a bridge graft, the assisted patency benefits of fistulae are questionable because grafts can be more reliably declotted than fistulas.^{7,17} Transposed vein configurations are durable, although they will usually require

multiple percutaneous maintenance interventions, and should be monitored by an organized surveillance program (i.e., physical exam supplement with a flow study).^{24,27} That said, the risk of infection with primary fistulae (wound infections aside) has approached zero with the subsequent loss of fistula being extremely uncommon. In contrast, the risk of graft infection is 4 to 5% and almost always leads to site loss. Clearly, the aggregate benefit favors autogenous fistulae over grafts.⁷

Secondary Vascular Access

Because of the ubiquitous use of TDCs, patients will frequently lose access options due to central vein stenosis/occlusion rendering the upper extremities unusable. Because of this, one should consider the lower extremities as a secondary vascular access option. The greater saphenous vein, because of its usually small caliber (<5 mm) and thicker wall, will not dilate and is a poor conduit. However, the femoral vein, with its large caliber, is an excellent conduit. It can be mobilized down to the popliteal level and transposed to yield a durable vascular access.²⁸ A technical pearl is that the vein should be mobilized through an aperture in the sartorius muscle to reduce kinking. Of course, the patient should have normal pedal perfusion and the arteriotomy size should be controlled to limit steal physiology down the leg. PBGs can be placed in the lower extremity if there are limitations for vein use (e.g., DVT, short stature, and limited vein length). The dissection should be performed at least 5 to 7 cm below the cutaneous groin crease to limit the rate of infectious complications.

Several options exist for conduit material when nonautogenous reconstruction is created. Most common is the use of expanded polytetrafluoroethylene (ePTFE) grafts. After graft creation, 2 to 3 weeks generally are required before cannulation can be performed. Incorporation involves the graft becoming densely fibrosed to soft tissues so that when needle cannulation is performed there is no potential space for hematoma formation. A new PTFE-based graft includes the Gore Accuseal graft (Newark, DE) that allows needle cannulation within 24 hours by way of a midlayer sealing membrane within a trilayer iteration. This graft is often used preferentially in revision of aneurysmal fistulae that heretofore required a catheter while awaiting incorporation. Bovine carotid artery and cadaveric vein graft have also been used as alternative conduits, although concerns exist about aneurysmal degeneration.

Surveillance

Historically, little has been recommended with regard to surveillance of vascular access despite the improvement in patency that occurs in all other vascular reconstructions that are monitored. Patients should be seen in follow-up every 3 to 4 months to examine the access for aneurysmal changes, review flow issues, and educate the patient on self-examination.²⁷ Surveillance duplex is not routinely used for monitoring. Immediate concerns following creation of vascular access traditionally include ischemic monomelic neuropathy and

steal syndrome, which if significant may require further surgical intervention. Additionally, patients may develop high-output heart failure or pulmonary hypertension, which can be noted in approximately 40% of HD patients.²⁸

Conclusion

With the increasing incidence of end-stage renal disease, HD vascular access presents an ongoing challenge, and a multi-disciplinary approach must be considered to provide long-term durable access for patients on chronic HD. Surgeons must be very thoughtful in planning the steps of access for these patients and consider fistula first and catheter last, without forgetting that prosthetic grafts may be a legitimate first option for some patients.

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