Creation and Maintenance of Hemodialysis Access

An overview of the technology and techniques for treating this increasingly large patient population.

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Surgical procedures for hemodialysis have become the most common vascular operation in the US. The establishment of hemodialysis access has been reformed with the availability of improved graft materials, the use of standardized operative approaches as suggested by National Kidney Foundation Dialysis Outcomes Quality Initiative (NKF-DOQI) guidelines, and the application of new techniques for treatment of failed fistulas and grafts by endovascular means.[1] This article reviews the contemporary creation and maintenance of hemodialysis access sites.

CENTRAL VENOUS CATHETERS

There are many double-lumen central venous hemodialysis catheters on the market. The main differentiating features are the presence or absence of a cuff, catheter pliability, and whether the catheter is tunneled under the skin.[2] According to DOQI guidelines, noncuffed, double-lumen catheters should be used for dialysis of less than 3 weeks' duration. They should be preferentially inserted under ultrasound guidance in the internal jugular or femoral vein positions. The subclavian site should be avoided because of the high rate of subsequent subclavian stenosis that may impede the use of the ipsilateral extremity for future access creation. For temporary access of longer than 3 weeks' duration, or for patients who have become catheter-dependent, tunneled, cuffed venous catheters are preferred. The ideal insertion site for temporary access is the right internal jugular vein. However, the catheter should not be placed ipsilateral to a maturing extremity fistula if possible. Tunneled catheters should be placed under fluoroscopic guidance to ensure proper positioning of the tip at the level of the atriocaval junction to ensure optimal blood flow.

CREATION OF PERIPHERAL ARTERIOVENOUS ACCESS

The gold standard for arteriovenous (AV) access for the last 38 years has been the radiocephalic arteriovenous fistula at the wrist. Spurred by the recommendations of the NKF-DOQI vascular access guidelines, a number of investigators have emphasized the use of preoperative imaging of the arterial and venous systems to determine, ahead of time, appropriate limbs for autogenous access creation.[3-5] Numerous studies have supported the premise that vein mapping increases autogenous access placement (incidence of arteriovenous access in a dialysis population), but few, if any, studies have substantiated that this approach increases the number of functional autogenous accesses (prevalence in a dialysis population).

A number of autogenous alternatives can be used for access construction, with varying reports of success. These alternatives include the antecubital radio- or brachiocephalic fistula, the transposed forearm basilic vein fistula, the transposed upper-arm basilic vein fistula, the superficial femoral vein fistula, and the transposed or *in situ* saphenous vein fistula. All of these options have their champions in the literature.[6-10] Our practice is to apply these techniques selectively, taking into account the patient's comorbid conditions, body habitus, and access history. Although the DOQI guidelines tout the advantages of autogenous access over prosthetic access, one must place into perspective the fact that little level I evidence existed as part of the DOQI vascular access literature review. In that context, the real goal for any patient with end-stage renal disease is a working access that provides as long a period of uninterrupted function as possible, regardless of construct.

For patients who do not have adequate autogenous tissue for access, or for those who are not candidates for autogenous access, prosthetic grafts provide the main vehicle for access, with complication rates that are less than those seen with tunneled catheter alternatives. Expanded polytetrafluoroethylene (ePTFE) remains the most common type of prosthetic graft placed. There are many construct modifications that have appeared to improved outcomes. The only modification with published advantages is the Venaflo carbon-coated, ePTFE graft with a built-in hood (Figure 1). In a randomized prospective study of this graft versus traditional ePTFE, a statistically significant improvement was demonstrated in both primary and secondary patency.[11] Other

Figure 1. Venaflo dialysis graft (C.R. Bard, Inc., Tempe, AZ) that combines ePTFE, carbon coating, and an expanded hood for the venous anastomosis for dialysis access.

prosthetic modifications that have emerged include the polyurethane graft (Vectra, C.R. Bard, Inc.), which allows for immediate access, the varied porosity family of ePTFE grafts (Advanta, Atrium Medical Corp., Hudson, NH), and the bovine mesenteric vein graft (Procol, Hancock Jaffe Laboratories, Inc., Irvine, CA).[12,13] Few data exist that compare these grafts to others on the market. Regardless of construct, one can expect a primary patency of approximately 50% at 12 months using prosthetic grafts for AV access, with a reliable secondary patency of 80% to 90%.[14]

ENDOVASCULAR CREATION OF HEMODIALYSIS ACCESS

The percutaneous creation of an AV fistula remains a holy grail for some interventionalists in the field of hemodialysis access. The pursuit largely revolves around the percutaneous generation of either an artery-to-vein anastomosis or graft-to-artery and graft-to-vein anastomoses. One of the first descriptions of an attempt at endovascular hemodialysis access construction appeared in 1998. Masuda et al described an endovascular-assisted AV graft in which the venous anastomosis was created using stent graft technology, while the arterial anastomosis was constructed in the conventional manner.[15] Eight patients had the experimental grafts placed; three (37.5%) remained patent at 1 year. Trerotola et al were one of the earliest groups to report results using a completely percutaneous AV graft in a canine model, although their results were limited by graft dislodgment.[16] To date, achievement of a functional percutanous AV access in humans has remained elusive in clinical practice but thrives in a number of laboratory investigations. The practical success of the percutaneous AV access concept is in question because there is little benefit to be gained over available open surgical procedures, which can be performed under local anesthesia in an outpatient setting.

An extrapolation of this concept does find clinical utility in present day practice. The availability of PTFE-encapsulated stents may provide a way to percutaneously revise the venous anastomosis of a failing or failed AV graft. Because the majority of AV graft failures results from venous anastomotic stenosis, current treatment revolves around balloon angioplasty of the stenosis either prior to graft thrombosis or after graft thrombectomy, if thrombosis has occurred. By treating the venous anastomotic stenosis with a PTFE-encapsulated stent, we have effectively revised or extended the graft more proximally on the vein through percutaneous means. The early report from a prospective trial of an investigational carbon-coated, PTFE-encapsulated nitinol stent graft (Figure 2) (C.R. Bard, Inc.) specifically designed for AV access failure has been encouraging. In a nonrandomized trial compared to percutaneous transluminal balloon angioplasty (PTA) alone, a primary patency of 72% at 6 months was achieved with use of this stent graft.[17] Despite these early data, we await the randomized comparison results for final judgment on the role of stent grafts in AV access failure. A number of other stent grafts have been used for treating AV access outflow stenoses. Unlike the Bard device, these grafts were designed for tracheobronchial stenoses but have been used as vascular stents. All three of the commercially available endobronchial stent grafts, including the aSpire stent (Vascular Architects, Santa Rosa, CA), the Viabhan (W. L. Gore & Associates, Flagstaff, AZ), and the Wallgraft (Boston Scientific Corporation, Natick, MA) have been used for AV access failure with variable results.[18]

ENDOVASCULAR TREATMENT OF FAILING OR FAILED HEMODIALYSIS ACCESS

Percutaneous Thrombectomy

Numerous studies have compared percutaneous declotting of AV access sites by open surgical means. The consensus opinion appears to be one of equipoise in terms of cost and efficacy for the two techniques. For the nonsurgical interventionalist who manages AV access, several percutaneous tools to perform thrombectomy in access sites have emerged during the last decade and will be described.

Percutaneous mechanical thrombectomy (PMT) devices emerged as a means to more rapidly clear clot from occluded vessels and thereby eliminate the need for thombolysis, or at least reduce the dosage of drug and the time required when thrombolysis was the only technique available (see page 64 for the PMT Device Chart). PMT devices are a natural evolution of the two techniques of pharmaceutical and mechanical thrombectomy and use a variety of forces to
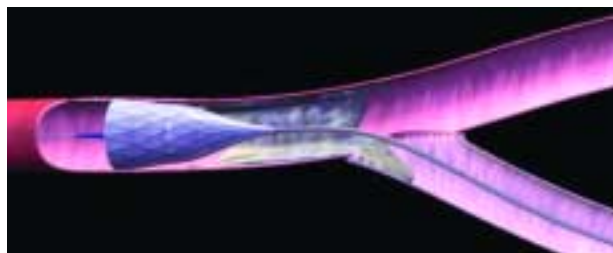
Figure 2. Deployment of a self-expanding, PTFE-encapsulated, carbon-lined nitinol endoluminal graft for dialysis access venous anastomotic stenosis.

macerate and/or remove clot from the access site. Although all of the available devices are effective at clearing the bulk of access thrombosis, removal of the arterial plug remains an elusive goal that still requires balloon dislodgment and embolization into the venous circulation, which may not be without consequence in the most fragile of patients.[19]

The Arrow-Trerotola Percutaneous Thrombolytic device (Arrow International, Inc., Reading, PA) was first described in 1998.[20] The Arrow-Trerotola device, which combines a clot-maceration basket with an aspiration system, is one of the most common in use. The system relies on a nitinol basket that rotates on a shaft and is available in two sizes to allow maximal wall contact. In a number of studies using the Arrow-Trerotola PMT system, procedural success was achieved in approximately 95% of cases.[21] One advantage of the Arrow-Trerotola device over other PMT systems is the ability to treat the arterial plug without the need for another catheter, as demonstrated by Lazarro et al.[22]

In contrast to the mechanical clot maceration systems, a number of PMT devices employ the effect of high-pressure saline to macerate the thrombus into particles that are not clinically significant in size. The AngioJet rheolytic catheter (Possis Medical Inc., Minneapolis, MN) makes use of the Venturi effect. Pressurized saline is directed from the catheter tip backward into the thrombus, which is then aspirated. The AngioJet fits through a 6-F sheath and accommodates a .035-inch wire. Veseley et al performed a prospective study randomizing 153 patients to either surgical thrombectomy or treatment using the AngioJet.[23] There was no difference in primary patency between the two groups, although the surgical group had more wound-related complications.

BALLOON ANGIOPLASTY

PTA remains the most common method for treating the stenoses that commonly develop in both autogenous arteriovenous fistulas and prosthetic arteriovenous grafts. In more than 90% of failed accesses, anatomic stenoses are the precipitating pathology, and the most common site is at or adjacent to the venous anastomosis of prosthetic AV

grafts.[24,25] Morbidity related to angioplasty is low, with the most common manifestations being site rupture, access thrombosis, and delayed pseudoaneurysm formation. Patency of PTA versus surgical revision has been shown to be equivalent, with a number of studies demonstrating less cost and complications with PTA compared to surgical interventions.[26] During the last decade, only a few new balloon technologies that could impact the outcomes of hemodialysis access intervention have appeared.

One of these balloon technologies includes the availability of ultrahigh-pressure balloons. Because the stenoses that develop in the venous outflow of AV access are noted to be quite resilient, they often require the use of high-pressure balloons (>20 atm) to achieve a successful result. One such balloon that has recently become available (Conquest, C.R. Bard, Inc.) allows inflations to 30 atm. Limited published experience to date demonstrates a benefit of ultrahigh-pressure balloons in overcoming the resistance of AV access venous stenoses.[27]

Another evolution in balloon technology that has been applied in AV access failure is the Cutting Balloon (Boston Scientific Corporation). Clinical experience with the Cutting Balloon is largely focused on the coronary circulation, but its application has been evaluated in the renal arteries and other peripheral arteries, as well as in AV access applications. Unfortunately, results to date in the use of the Cutting Balloon for AV access venous stenoses have been disappointing, showing only equivalence to conventional PTA.[28,29]

ADJUNCTS TO ANGIOPLASTY

Balloon angioplasty remains the most common methodology to treat AV access failure. When PTA is inadequate, few options remain to salvage the access. Prior to the availability of endoluminal grafts, bare stents were used to treat refractory stenoses. Early reports using balloon-expandable Palmaz stents and subsequent reports using self-expanding stainless steel and nitinol stents have all shared the same limitation of poor long-term (>6 months) patency. In a prospective, randomized trial of PTA alone versus PTA plus stenting for venous stenosis or occlusion, Quinn et al demonstrated no difference in 60-, 180-, and 360-day primary or secondary patency between the two groups for peripheral lesions or central venous lesions.[30] Although long-term primary patency is poor, stents may have a role in the axillary and central venous positions as a last-ditch effort to maintain access in the ipsilateral extremity.[31,32] Anecdotal experience with this approach often includes scheduled periodic prophylactic fistulography and angioplasty, although no data exist to support this approach.

Percutaneous atherectomy also has been applied for resistant dialysis access stenoses to debulk the intimal hyperplasia. Unfortunately, experience to date with using this

technology in improving the results of balloon angioplasty alone has been disappointing.[33,34]

Finally, based on the success seen with coronary and peripheral arterial interventions for recurrent stenosis, brachytherapy with ionizing radiation is being evaluated as an adjunct for recurrent access stenoses. Currently, a randomized, double-blind trial of brachytherapy for AV access graft venous stenosis is underway that will likely define the utility of this modality for access failure.

SUMMARY

Fueled by DOQI, the emphasis during the last decade has been to maximize the use of autogenous fistulas. Detailed preoperative imaging may help us achieve this goal, although the realistic prevalence rate for autogenous access given the US patient population has yet to be accurately established. Dialysis catheters continue to function as important bridges to permanent access in both the acute and chronic setting, and for permanent access in the sickest of patients. Evolution in dialysis graft technology strives to achieve performance results that rival autogenous access in patients not suitable for native fistula creation. For the failed or failing access, few if any technologies to date have compared with balloon angioplasty in treating venous anastomotic stenosis, the most common cause of access failure. Currently, only one stent graft device has been uniquely designed for this pathology, which incorporates the principles of access graft design and self-expanding stent technology. Technology to clear the clot out of a thrombosed graft continues to evolve, but will never be as cost-effective as a simple balloon thrombectomy. However, the pressure placed on providers to perform only percutaneous interventions and move away from open techniques continues to fuel interest in this component of treatment. In the absence of limitations or national treatment guidelines geared to keep a tight rein on who receives dialysis, this population and the clinical challenges it poses will continue to enlarge without bound and provide endovascular specialists with clinically challenging problems, requiring new and revolutionary technology. ■

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