Dialysis Access Anatomy and Interventions: A Primer

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Abstract

The creation of arteriovenous fistulae and the use of arteriovenous grafts are a vital component in the treatment of patients undergoing dialysis. For many patients in this population, these accesses represent the permanent solution to their dialysis needs. Understanding the basic anatomy of the most common accesses used, as well as initial treatment of many underlying causes of access failure is vital for any interventionalist performing such procedures. This article outlines the most common approaches to surgically placed accesses used for renal replacement therapy, as well as the basics of interventional approaches used to treat the most common abnormalities causing their dysfunction.

Keywords
- ► dialysis
- ► interventional radiology
- ► surgical approaches
- ► angioplasty

Objectives: Upon completion of this article, the reader will be able to describe the most common approaches to surgical dialysis accesses, the anatomy associated with such surgical procedures, and the basic interventions performed for dysfunctional accesses.

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CME Objectives: After reading this article, the reader should understand the most common approaches to surgical dialysis accesses, the anatomy associated with such surgical procedures, and the basic interventions performed for dysfunctional accesses.

Renal replacement therapies include peritoneal dialysis (6.4%), renal transplant (29.3%), and the most common form, hemodialysis (64.2%).[1,2] The National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF-KDOQI) vascular access guidelines point to anarteriovenous fistula (AVF) as the optimal access for administration of hemodialysis. Other methods for performing hemodialysis include arteriovenous grafts (AVG), as well as tunneled and nontunneled catheters. Arteriovenous fistulas are associated with a greater long term patency rate (58 - 70 months) compared with arteriovenous grafts (18–months), with lower rates of thrombosis, as well as infection (infection rates of 1 per 200 years for native fistula versus 1 per 13.5 years for synthetic grafts.[3] Central venous catheters have the highest rates of complications, most commonly thrombosis and infection[1,4]; tunneled and nontunneled catheters have the highest rate of infection in comparison to all types of hemodialysis administration (32.6X and 13.6X higher than native fistulae and grafts, respectively).[5]

Anatomy of the Dialysis Access Fistula

The three most common types of AVFs include the radiocephalic fistula, the brachiocephalic fistula, and the brachial artery-to-transposed basilic vein fistula. The radiocephalic fistula, also referred to as the Brescia-Cimino fistula, is a forearm fistula created by anastomosing the end of the cephalic vein to the side of the radial artery. Such access was first described in 1966[6] and the 2006 KDOQI guidelines,

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recommended it as the first choice for fistula creation.[2,7] This recommendation arises from the ability to preserve future options for access sites more centrally, as well as a lower rate of steal syndrome in comparison to upper arm fistulas.[8,9] The main drawback to the Brescia-Cimino fistula is that they suffer from a high rate of poor maturation,[10] with the major cause of nonmaturation being secondary to juxta-anastomotic stenoses.[11] Juxta-anastomotic stenoses have been defined as either a greater than 50% reduction in the luminal diameter of the outflow vein within two centimeters, or greater than 5 cm, from the arteriovenous anastomosis.[2,11,12]

KDOQI guidelines also state that the preferred access in the upper arm is the brachiocephalic fistula.[2,7] This is the fistula of choice in patients in whom a forearm fistula is not feasible due to either inadequacy of the caliber of the vessels or a prior forearm fistula that has failed. A brachiocephalic fistula is created by anastomosing the cephalic vein to the brachial artery in an end-to-side manner, just central to the antecubital fossa. Although this type of fistula has lower rates of nonmaturation and better long-term patency rates, its placement precludes any future consideration of forearm fistula creation. Furthermore, there is an increased rate of steal syndrome in comparison to the radiocephalic graft (5–20% versus 1%, respectively).[7] The most common cause for a brachiocephalic fistula to fail is due to a stenosis in the cephalic arch.

If neither a radiocephalic nor a brachiocephalic fistula are possible, KDOQI guidelines recommend consideration of placement of a brachial artery –to-transposed basilic vein fistula.[7] This is performed by anastomosing the brachial artery to the basilic vein just above the antecubital fossa, and then returning to surgery 1–2 months later after the vein has arterialized. At this point, the basilic vein is transected peripheral to the brachial vein, the vessel tunneled laterally and superficially, and then re-anastomosed to the brachial vein.[13] This AVF requires a higher level of skill in creation, and carries increased perioperative morbidity.[13] The most common site of stenosis of the brachial artery-to-transposed basilic vein fistula is within the proximal swing segment, defined as the surgical curve of the basilic vein just peripheral to the anastomosis to the brachial vein. It is at this location that 70–75% of stenoses in these fistula occur.[13]

Angioplasty of the Failing Arteriovenous Fistula

Percutaneous transluminal angioplasty (PTA) should be performed in the dysfunctional AVF to restore adequate flow through the circuit, and to address any hemodynamically significant stenosis. Over the lifetime of an AVF, nearly all patients will require intervention with at least angioplasty for such indications as inadequate dialysis, prolonged bleeding, difficult cannulation, thrombosis, or a swollen extremity. A thrombosed AVF is the eventual progression of an unrecognized or inadequately treated stenosis in the inflow or outflow, arising from a failing access, many times with causes similar to a non-maturing circuit. Furthermore, to minimize the likelihood of short-term rethrombosis, the arterial inflow must be evaluated and confirmed to be widely patent. If the arterial anastomosis is thrombosed or stenotic, inadequate arterial inflow will cause any AVF to fail. Tessitore, et al. demonstrated that prophylactic PTA of stenoses in the functioning forearm AVF improves access survival and decreases access-related morbidity, supporting the usefulness of preventive correction of a stenosis before the development of access dysfunction.[14] In general, a technical success in PTA has been defined as the visual presence of <30% residual stenosis. Additionally, palpation of a good thrill or bruit on physical examination post-procedure suggests success.

Anatomy of the Dialysis Access Graft

Prosthetic arteriovenous grafts (AVG) are still commonly used for dialysis access despite their well-documented long-term inferiority to autologous arteriovenous fistulas (AVF).[2,15] AVGs are typically created following surgical anastomosis of a polytetrafluoroethylene (PTFE) conduit between an artery and a vein. In the upper extremity, this can be accomplished via a medial-to-lateral graft between the brachial artery and cephalic vein (brachiocephalic) in the forearm, or a lateral-to-medial graft between the brachial artery and the basilic vein in the upper arm. These are typically formed in either a looped or straight configuration. Graft placement in the thigh can also be accomplished using a looped graft between the superficial femoral artery and greater saphenous vein.

While AVGs have a lower rate of primary failure compared with AVF (15 vs 50%, respectively),[16] the long-term patency rates are inferior to AVFs (median lifetime of 12–18 months compared with 3–7 years, respectively).[17] Diligent graft surveillance is critical to maintaining viability of an AVG, as treating stenosis prior to graft thrombosis promotes overall survival.[18,19]

Dysfunctional Hemodialysis Arteriovenous Grafts (AVG)

AVG dysfunction is defined by the ACR-SIR practice parameters as "…an access that has a hemodynamically significant stenosis (>50% reduction in normal vessel diameter) with an abnormal hemodynamic or clinical indicator."[20] These indicators include: change in physical examination characteristics of the thrill, elevated venous pressures during hemodialysis, increased intra-access blood flow during dialysis, swollen extremity, reduced dialysis kinetics, prolonged bleeding after discontinuing dialysis access needles, elevated negative arterial pre-pump pressures preventing acceptable flow, or abnormal recirculation values.

A hemodynamically significant stenosis is characterized into three main categories: inflow, intragraft, or outflow stenosis. An inflow stenosis is typically related to disease of the inflow artery or narrowing at the arterial anastomosis. Intragraft problems are largely caused by an intragraft stenosis, or less commonly from extrinsic compression or architectural distortion of the graft material. An outflow stenosis can occur at the venous-graft anastomosis, within the draining veins, or centrally. The vast majority (58%) of AVG functional stenoses occur at or within 1 cm of the venous anastomosis. Stenosis within the graft (2%) or at the arterial anastomosis (4%) is uncommonly noted.[21] Over 90% of thrombosed hemodialysis accesses are secondary to underlying anatomic stenosis, with the small remaining fraction caused by physiological phenomena such as hypotension or hypoperfusion.[20]

Arteriovenous Graft Treatment Options

Management of a dysfunctional AVG can be performed by percutaneous or non-percutaneous (surgical) techniques. Surgical thrombectomy is prone to failure due to the lack of treatment of the inciting stenosis. Surgical salvage techniques including graft revision demonstrate improved 30 and 120-day patency rates compared with thrombectomy alone (59 and 25% versus 30 and 10%, respectively).[22]

Percutaneous transluminal angioplasty has been the preferred method of intervention for AVG dysfunction, but patency rates do not exceed 50% after 3 years of initial access creation.[2,15] Stent placement is generally not preferred, since preservation of native veins remains a prime consideration in these patients for future autologous fistula creation. The Society of Interventional Radiology guideline for post-intervention patency rates is 40% at 3 and 6 months for thrombosed and non-thrombosed AVGs, respectively.[23] Angioplasty is typically performed using 6–10 mm high-pressure noncompliant balloons inflated to ~20–24 atm. A successful result is indicated by less than 30% residual stenosis following intervention. Studies investigating the duration of balloon inflation have reported an increased technical success rate achieved after 3- vs 1-minute inflation times (89 vs 75%, respectively) but no significant difference was noted in the 1, 3 and 6-month patency rates.[2,24]

Comparisons in the effectiveness of traditional balloon PTA versus cutting-balloon PTA have been made in the setting of AVGs. These results demonstrated improved primary patency rates following the use of cutting-balloon PTA vs traditional PTA for venous-graft anastomosis stenosis (86 and 63% versus 56 and 37% at 6 and 12 months), respectively.[25] Drug delivery via balloons has also been investigated, with one study reporting no significant improvement in patency of venous outflow stenoses with heparin and hydrogel-coated balloon PTA.[26]

The use of drug-eluting balloons has shown promise in the peripheral arterial system, but its application in AVG and AVFs is likely limited by the differing underlying pathophysiology of stenoses in these systems; these stenoses are primarily related to neointimal hyperplasia related to unfavorable hemodynamics from high pressures in a low-pressure native system. One small prospective trial, however, has shown an increased 6-month post-intervention patency rate following the use of paclitaxel-coated compared with standard high-pressure balloon PTA (75 vs 25%, respectively).[27] Perforation following PTA of AVGs was found to be a rare complication occurring in ~0.9% of interventions. This complication was believed to be related to using balloons > 2 mm than the diameter of the host vessel or through use of a cutting balloon.[28]

Summary

The placement of AVF and AVG are a vital component of the delivery of hemodialysis. Knowledge of the anatomy, surgical approaches, and the use of endovascular interventions in these important accesses is necessary for any operator performing such procedures.

References

1 Ravani P, Palmer SC, Oliver MJ, et al. Associations between hemodialysis access type and clinical outcomes: a systematic review. J Am Soc Nephrol 2013;24(3):465–473
2 Quencer KB, Arici M. Arteriovenous fistulas and their characteristic sites of stenosis. AJR Am J Roentgenol 2015;205(4):726–734
3 Chazan JA, London MR, Pono LM. Long-term survival of vascular accesses in a large chronic hemodialysis population. Nephron 1995;69(3):228–233
4 Dhingra RK, Young EW, Hulbert-Shearon TE, Leavey SF, Port FK. Type of vascular access and mortality in U.S. hemodialysis patients. Kidney Int 2001;60(4):1443–1451
5 Stevenson KB, Hannah EL, Lowder CA, et al. Epidemiology of hemodialysis vascular access infections from longitudinal infection surveillance data: predicting the impact of NKF-DOQI clinical practice guidelines for vascular access. Am J Kidney Dis 2002; 39(3):549–555
6 Brescia MJ, Cimino JE, Appel K, Hurwich BJ. Chronic hemodialysis using venipuncture and a surgically created arteriovenous fistula. N Engl J Med 1966;275(20):1089–1092
7 Zaleski G. Declotting, maintenance, and avoiding procedural complications of native arteriovenous fistulae. Semin Intervent Radiol 2004;21(2):83–93
8 Weiswasser JM, Kellicut D, Arora S, Sidawy AN. Strategies of arteriovenous dialysis access. Semin Vasc Surg 2004;17(1):10–18
9 Mickley V. Steal syndrome—strategies to preserve vascular access and extremity. Nephrol Dial Transplant 2008;23(1):19–24
10 Nassar GM, Nguyen B, Rhee E, Achkar K. Endovascular treatment of the "failing to mature" arteriovenous fistula. Clin J Am Soc Nephrol 2006;1(2):275–280
11 Perera GB, Mueller MP, Kubaska SM, Wilson SE, Lawrence PF, Fujitani RM. Superiority of autogenous arteriovenous hemodialysis access: maintenance of function with fewer secondary interventions. Ann Vasc Surg 2004;18(1):66–73
12 Asif A, Gadalean FN, Merrill D, et al. Inflow stenosis in arteriovenous fistulas and grafts: a multicenter, prospective study. Kidney Int 2005;67(5):1986–1992
13 Kakkos SK, Haddad GK, Weaver MR, Haddad RK, Scully MM. Basilic vein transposition: what is the optimal technique? Eur J Vasc Endovasc Surg 2010;39(5):612–619
14 Tessitore N, Mansueto G, Bedogna V, et al. A prospective controlled trial on effect of percutaneous transluminal angioplasty on functioning arteriovenous fistulae survival. J Am Soc Nephrol 2003; 14(6):1623–1627
15 National Kidney Foundation-Dialysis Outcomes Quality Initiative. NKF-DOQI clinical practice guidelines for vascular access. Am J Kidney Dis 1997;30(4, Suppl 3):S150–S191
16 John A. Bittl, MD. "Catheter Interventions for Hemodialysis Fistulas and Grafts. J Am Coll Cardiol Intv 2010;3(1):1–11
17 Huber TS, Carter JW, Carter RL, Seeger JM. Patency of autogenous and polytetrafluoroethylene upper extremity arteriovenous hemodialysis accesses: a systematic review. J Vasc Surg 2003;38(5):1005–1011
18 Roberts AB, Kahn MB, Bradford S, et al. Graft surveillance and angioplasty prolongs dialysis graft patency. J Am Coll Surg 1996; 183(5):486–492
19 Martin LG, MacDonald MJ, Kikeri D, Cotsonis GA, Harker LA, Lumsden AB. Prophylactic angioplasty reduces thrombosis in virgin ePTFE arteriovenous dialysis grafts with greater than 50% stenosis: subset analysis of a prospectively randomized study. J Vasc Interv Radiol 1999;10(4):389–396
20 2006, NKF-K/DOQI Clinical Practice Guidelines for Vascular Access: update. American College of Radiology. ACR–SIR PRACTICE

PARAMETER FOR ENDOVASCULAR MANAGEMENT OF THE THROMBOSED OR DYSFUNCTIONAL DIALYSIS ACCESS. acr.org. 2014. http//www.acr.org. Accessed November 2015

21 Kanterman RY, Vesely TM, Pilgram TK, Guy BW, Windus DW, Picus D. Dialysis access grafts: anatomic location of venous stenosis and results of angioplasty. Radiology 1995;195(1):135–139

22 Brotman DN, Fandos L, Faust GR, Doscher W, Cohen JR. Hemodialysis graft salvage. J Am Coll Surg 1994;178(5):431–434

23 Aruny JE, Lewis CA, Cardella JF, et al; Society of Interventional Radiology Standards of Practice Committee. Quality improvement guidelines for percutaneous management of the thrombosed or dysfunctional dialysis access. J Vasc Interv Radiol 2003;14(9 Pt 2): S247–S253

24 Forauer AR, Hoffer EK, Homa K. Dialysis access venous stenoses: treatment with balloon angioplasty—1- versus 3-minute inflation times. Radiology 2008;249(1):375–381

25 Saleh HM, Gabr AK, Tawfik MM, Abouellail H. Prospective, randomized study of cutting balloon angioplasty versus conventional balloon angioplasty for the treatment of hemodialysis access stenoses. J Vasc Surg 2014;60(3):735–740

26 Sheley RC, Schuman ES, Standage BA, Ragsdale JW, Feliciano PD, Quinn SF. Local delivery of heparin with balloon angioplasty: results of a prospective randomized trial. J Vasc Interv Radiol 1996;7(6):853–858

27 Katsanos K, Karnabatidis D, Kitrou P, Spiliopoulos S, Christeas N, Siablis D. Paclitaxel-coated balloon angioplasty vs. plain balloon dilation for the treatment of failing dialysis access: 6-month interim results from a prospective randomized controlled trial. J Endovasc Ther 2012;19(2):263–272

28 Bittl JA. Venous rupture during percutaneous treatment of hemodialysis fistulas and grafts. Catheter Cardiovasc Interv 2009: 1097–1101