

Balloon-Assisted Maturation of Arteriovenous Fistulas

The important role that endovascular techniques play in helping the dialysis community meet their goals.

BY GREGG MILLER, MD, AND ALEX FRIEDMAN, BA

During the 1980s and early 1990s, the arteriovenous graft was the most common hemodialysis vascular access placed by surgeons in the United States due to favorable reimbursement rates, high technical success of surgical placement, and a relatively short time (2 weeks) required for hemodialysis adequacy. A relatively short median primary patency of 3 to 6 months and secondary patency of 12 to 18 months as a result of access thrombosis and dysfunction necessitated frequent revisions, which were a significant source of patient morbidity. High infection rates and frequent usage of hemodialysis catheters led to innumerable complications and skyrocketing costs. However, the new millennium saw the resurgence of the native vein fistula after it demonstrated higher durability, lower long-term costs, and lower rates of infections and complications.¹

Since the Centers for Medicare & Medicaid Services recognized the clinical and economic advantages of arteriovenous fistulas (AVFs), the National Kidney Foundation's Kidney Disease Outcomes Quality Initiative (KDOQI) and the Fistula First Initiative have made increasing the prevalence of AVFs a priority.^{2,3} However, fistulas are at higher risk of early failure, with a rate of 38% to 60%⁴⁻⁶ compared to 15% to 23% in grafts.^{5,7,8} Because maturation failure represents the most significant shortcoming of this type of vascular access,^{1,7} improvements in techniques to salvage nonmaturing fistulas are key to increasing their prevalence.

An oversimplified view of maturation failure is that it is just one phenomenon. On the contrary, the barriers to AVF usage include early thrombosis and an inability to be successfully and repeatedly cannulated, as well as the failure to support the flow rates needed to achieve adequate

hemodialysis clearance. The KDOQI "Rule of 6s" suggests that a fistula can be used when it is at least 6 mm in diameter, < 6 mm deep, and has a blood flow > 600 mL/min. However, with maturation failure rates as high as 60%,⁴ a greater understanding of what it takes to make an AVF useable is necessary.

The perfect candidate for a Brescia-Cimino fistula is a patient with a 4-mm-diameter radial artery, 6-mm-diameter forearm cephalic vein 2 mm below the skin surface, and enough subcutaneous elastic tissue to prevent perforation and extravasation upon needle placement. The reality of a fistula that fails to mature is that many of our patients meet none of the aforementioned criteria. More typical is the vasculopath patient with a 2.5-mm-diameter radial artery and a 3-mm-diameter cephalic vein. Competing branch vessels (collaterals) are particularly problematic because, when numerous, they can have the flow-carrying capacity of three to four times the fistula flow than the intended fistula vein, preventing flow-mediated dilation. The problem can be further compounded by obesity, which results in a vein that is 8 to 12 mm deep. When these factors are coupled with advanced age and poor tissue elasticity, the fistula does not stand a chance.

When the Fistula First Initiative began, the thrust of the campaign was simply to create more AVFs preferentially over arteriovenous grafts. As it turns out, shifting toward more incident AVFs was the easy part because the effect on AVF prevalence was muted. The result was a resurgence of catheter dependency while waiting for fistulas to either fail or mature.⁹ As the understanding necessary to promote maturation of failing fistulas has evolved, the old "watch-and-wait" approach to fistula maturation has been



Figure 1. Selected AVF vein with brachial vein outflow (arrows).



Figure 2. A 4-mm X 10-cm Symmetry balloon (Boston Scientific Corporation, Natick, MA) and 0.018-inch guidewire.

replaced by early endovascular interventions over abandonment and surgical revision. KDOQI guidelines support evaluating fistulas for failure to mature if they are not usable at 6 to 8 weeks. More recently, accelerated maturation techniques including forced balloon angioplasty maturation (BAM) of both arterial and venous segments as long as 20 to 30 cm in length have been promoted to rapidly facilitate AVF usage in as little as 2 to 6 weeks after the initial 6- to 8-week waiting period.

Previously, the vascular technology applied to fistula maturation was based on an arterial—rather than a venous—model and consisted solely of angioplasty treatment of focal venous stenoses. Advances in balloon catheter technology, along with a comprehensive approach to address all of the previously mentioned arterial and venous pathologies, have been shown to promote fistula maturation. The culmination of many authors' studies has made possible the understanding of fistula maturation we have today.

Clark et al,¹⁰ along with others,¹¹⁻¹⁴ linked nonmaturation of AVFs to stenotic lesions within the access, while Beathard et al has proposed that competing side branches unrelated to stenosis account for inadequate maturation.^{11,15} Endovascular interventional techniques proved to be successful in treating both problems using percutaneous transluminal angioplasty to treat focal stenoses and coil embolization and ligation to eliminate competing branch veins.^{10-12,14,16,17} Nassar et al used balloon angioplasty of focal stenoses and coil embolization of accessory veins to salvage 83% of nonmaturing fistulas but concluded that 16.8% of fistulas were unsalvageable due to complete occlusion of

the outflow tract or the venous outflow tract being prohibitively deep, tortuous, or strictured.¹⁶ Turmel-Rodrigues et al recently facilitated maturation in 96% of patients with failing Brescia-Cimino fistulas who underwent long-segment arterial angioplasty of the radial artery to 4 mm in diameter to support the flow rates necessary to promote maturation.¹⁸

In our 2009 study published in the *Journal of Vascular Access*, we salvaged 118 of 122 nonmaturing fistulas by simultaneously dilating both focal and long-segment arterial and venous stenoses and eliminating collateral veins.¹⁹ An important aspect of this study was the concept of relative fistula depth and its impact on maturation; fistula diameter and depth are interdependent factors, and the appropriate diameter for a fistula is relative to the depth of the target vein. For example, a 6-mm-diameter vein that is 10-mm deep will be very difficult to cannulate, but a 12-mm-diameter vein that is 10-mm deep should be a much larger subcutaneous target and therefore easier to cannulate. Although Nassar et al salvaged 83% of AVFs, we were able to salvage 97% of nonmatured AVFs with a more aggressive approach to dilating diffusely strictured veins, forced BAM of deep veins up to 16 mm in diameter, and elimination of nearly all distal and mid-fistula collateral veins. These otherwise abandoned AVFs were successfully matured and supported hemodialysis in as little as 1 to 6 weeks after the initial angioplasty.

A complex series of techniques are used to successfully mature AVFs. First, detailed ultrasonography of the AVF is performed to determine the vein size (1–3 mm, 3–6 mm, > 6 mm), fistula vein depth (greater or less than 6 mm),



Figure 3. Angioplasty up to 6-mm diameter at the first procedure. Mild extravasation controlled by the limited controlled extravasation technique.

location of competing branch veins (if any), and the best site for micropuncture needle cannulation. Small veins require an initial sheathless approach and use of 0.018-inch wires and balloon catheters to prevent occlusion of the lumen by a sheath. Frequently, the best site for initial cannulation is under ultrasound guidance into the distal radial artery or in an outflow vein where the lumen is larger. Bidirectional wires should always be present to stabilize both inflow and outflow venous and arterial pathways before the initial angioplasty. Heparin is generally not necessary, but if long segments of vein (> 10 cm) require angioplasty, 3,000 units of heparin should be administered.

Ultrasound will also help determine if the fistula has a primary outflow vein. Frequently, numerous outflow choices exist, and the primary outflow should be chosen with the strongest consideration given to whether it has a straight-line pathway that connects into the brachial and basilic veins. Angioplasty of this selected vein, no matter how initially small in diameter, should occur in 1-mm increments up to 6 mm at the first visit. Residual collateral vessels that continue to show diversion of flow on angiography should then be eliminated. Bidirectional access should be used to dilate all segments of the fistula with long-length balloons from the arterial anastomosis to the outflow veins. Significant venous spasm after angioplasty indicates that a larger balloon is needed to fracture the circumferential muscle fibers that are contracting in response to an undersized balloon.



Figure 4. Final image at the end of the first visit.

TECHNIQUES FOR MATURATION

Flow rerouting is a deliberate process of diverting blood flow into veins that are known to have straight line flow to the central circulation. Under road map guidance, a guidewire is used to traverse the intended fistula vein. Then, balloon angioplasty follows the guidewire, and a pathway of least resistance is created (Figure 1).

Staged balloon angioplasty maturation with long-length balloons (80–100 mm) entails sequentially dilating the entire length of the fistula body to increase the fistula target size for cannulation (Figures 2 through 4). Dilatation of the fistula is performed with an angioplasty balloon to treat any focal stenoses or to simply upsize the entire length of the fistula. Any residual stenoses are then fully effaced using ultra-high-pressure balloons at up to 36 atm.

Limited controlled extravasation is an arterial inflow control technique and systematic process of angioplasty across the proximal vein (toward central and outflow) followed by the distal vein (toward periphery and arterial anastomosis) to avoid inflow pressure from exerting pressure forces on angioplasty-weakened tissues. This technique utilizes either an inflow occlusion balloon or manual pressure on the arterial anastomosis. Inflow control must be maintained during all phases of balloon inflation/deflation to avoid intrafistula pressure spikes with subsequent back-pressure injuries, complicating angioplasty across long segments of vein (Figure 5).

Competing branch vein elimination involves coil embolization or surgical ligation of competing branch

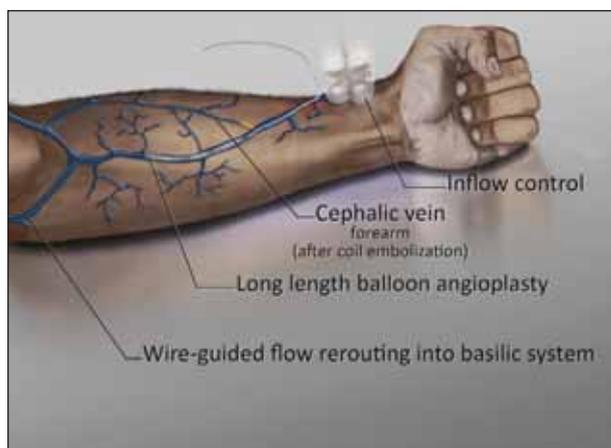


Figure 5. Limited controlled extravasation via manual pressure.

veins (Figure 6). Veins should only be considered to be significant only if they are 3 to 8 mm in diameter and have a persistent high-velocity imaged flow or a palpable thrill after angioplasty of the main fistula channel. Coil embolization is the method of choice for veins deeper than 3 mm. Surgical ligation of competing branch veins is used to eliminate superficial veins (< 3 mm deep).

Vessel thickening angioplasty refers to a method of angioplasty we use to help elderly patients with exceedingly thin skin avoid severe infiltrations upon needle cannulation. Angioplasty of a 6-mm-diameter vein with a 7-mm-diameter balloon will result in fracture of the wall and inflammation of the vein. Three weeks after angioplasty, the vein dilates and the wall thickens. Inflammation of the vein wall also facilitates incorporation of the skin with the vein wall, which is essential in preventing infiltrations.

THE MATURATION PROCESS

Usually, a fistula < 6 mm deep is ready for use after the first maturation treatment. Deeper fistulas must have a larger circumference in order to be cannulated and therefore require more maturation procedures. Continue to angioplasty the AVF in this manner every 2 to 3 weeks until it becomes suitable for dialysis and easy to cannulate (Figures 3, 7, and 8). This 2- to 3-week interval between angioplasty procedures is necessary to allow for healing of the vessel wall.

OUR RESULTS

We successfully matured 118 of 122 fistulas. The four failures were patients who presented with an occluded venous outflow tract that could not be traversed using a 0.018-inch wire. The majority were successfully salvaged and required 1.5 interventions per access year. The secondary patency of these salvaged accesses was 75% at 12 months. The mean



Figure 6. After the first angioplasty, using a 4-mm balloon. Collateral no longer visualized (dotted line).

follow-up was 24 months (range, 0.25–60 months). Patients with upper arm fistulas (n = 14) required 24 cephalic arch venous stents. Eight of these patients received their initial stent during the first maturation procedure. Other interventions during the follow-up period included treatment for steal syndrome (n = 4) and development of pseudoaneurysms (n = 4). Steal syndrome was treated with minimally invasive limited ligation endoluminal-assisted revision (MILLER) banding procedures (n = 5) and coil embolization of the distal radial artery (n = 1).²⁰⁻²² Pseudoaneurysms were treated with angioplasty of venous outflow stenoses and banding (flow reduction) to minimize intra-access pressures. In one case, a stent graft was placed in the mid-fistula to treat an angioplasty-mediated blowout pseudoaneurysm in a forearm fistula. During the course of 3 years, 13 patients required a total of 22 thrombectomy procedures to maintain access patency.

Most interestingly, when patency outcomes were stratified by initial vein size, there was no difference in long-term patency, indicating that aggressive angioplasty does not necessarily result in intimal hyperplasia and venous stricture. To the contrary, aggressive angioplasty, when performed using the aforementioned techniques, can result in a dilated, durable vein, which is the desired result of access salvage.

CONCLUSION

Critics of such aggressive interventional techniques have not yet recognized the inherent difference of arterial and venous angioplasty. Although arterial angioplasty is general-



Figure 7. Final image at the end of second visit (3 weeks after the first visit). AVF vein has been dilated to an 8-mm diameter.



Figure 8. AVF 18 months after the initial procedure.

ly angioplasty of the lumen, intima, and media, when venous angioplasty is performed for the purpose of fistula maturation, it involves rupture of the entire vessel wall with a reliance on subcutaneous tissue to contain fistula flow and pressure. We believe that continuous arterial pressure exerted on the injured walls of the vein precipitates ongoing fistula dilation rather than injury-mediated sclerosis and stenosis of the vein wall. The end result is a collagen tube that is thick and durable. Thus, although some vascular biologists have argued that angioplasty only increases the rate of restenosis,²³ we see our results as validating this approach to fistula maturation.

Endovascular techniques have an important role to play in helping the dialysis community meet the goals of the Fistula First Initiative. To meet these goals, the previously mentioned techniques need to be used in varying degrees to salvage > 95% of the nearly 60% of AVFs that fail to mature. When prolonged catheter time is taken into account, it is imperative to have a systematic method for salvaging these failing accesses before catheter-related complications are encountered. ■

Gregg Miller, MD, is Chief Medical Officer with the American Access Care of Brooklyn in New York. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein. Dr. Miller may be reached at (718) 369-1444; vascular1@att.net.

Alex Friedman, BA, is a research assistant with the American Access Care of Brooklyn in New York. He has disclosed that he holds no financial interest in any product or manufacturer mentioned herein.

1. Allon M, Robbin ML. Increasing arteriovenous fistulas in hemodialysis patients: problems and solutions. *Kidney Int.* 2002;62:1109-1124.
2. National Kidney Foundation. KDOQI clinical practice guidelines and clinical practice recommendations for hemodialysis adequacy, peritoneal dialysis adequacy, and vascular access: 2006 Updates. *Am J Kidney Dis.* 2006;48:S1-S322.
3. Peters VJ, Clemons G, Augustine B. "Fistula First" as a CMS breakthrough initiative: improving vascular access through collaboration. *Nephrol Nurs J.* 2005;32:686-687.
4. Dember LM, Beck GJ, Allon M, et al. Effect of clopidogrel on early failure of arteriovenous fistulas for hemodialysis: a randomized controlled trial. *JAMA.* 2008;299:2164-2171.
5. Allon M, Lockhart ME, Lilly RZ, et al. Effect of preoperative sonographic mapping on vascular access outcomes in hemodialysis patients. *Kidney Int.* 2001;60:2013-2020.
6. Miller PE, Tolwani A, Lusczy CP, et al. Predictors of adequacy of arteriovenous fistulas in hemodialysis patients. *Kidney Int.* 1999;56:275-280.
7. Oliver MJ, McCann RL, Indridason OS, et al. Comparison of transposed brachiocephalic fistulas to upper arm grafts and brachiocephalic fistulas. *Kidney Int.* 2001;60:1532-1539.
8. Dixon BS, Novak L, Fangman J. Hemodialysis vascular access survival: upper-arm native arteriovenous fistula. *Am J Kidney Dis.* 2002;39:92-101.
9. Patel ST, Hughes J, Mills JL Sr. Failure of arteriovenous fistula maturation: an unintended consequence of exceeding dialysis outcome quality initiative guidelines for hemodialysis access. *J Vasc Surg.* 2003;38:439-445; discussion 445.
10. Clark TW, Cohen RA, Kwak A, et al. Salvage of nonmaturing native fistulas by using angioplasty. *Radiology.* 2007;242:286-292.
11. Beathard GA, Arnold P, Jackson J, et al. Aggressive treatment of early fistula failure. *Kidney Int.* 2003;64:1487-1494.
12. Shin SW, Do YS, Choo SW, et al. Salvage of immature arteriovenous fistulas with percutaneous transluminal angioplasty. *Cardiovasc Intervent Radiol.* 2005;28:434-438.
13. National Kidney Foundation. KDOQI Clinical Practice Guidelines for Hemodialysis Adequacy: update 2000. *Am J Kidney Dis.* 2001;37:S7-S64.
14. Turmel-Rodrigues L, Mouton A, Birmele B, et al. Salvage of immature forearm fistulas for haemodialysis by interventional radiology. *Nephrol Dial Transplant.* 2001;16:2365-2371.
15. Beathard GA, Settle SM, Shields MW. Salvage of the nonfunctioning arteriovenous fistula. *Am J Kidney Dis.* 1999;33:910-916.
16. Nassar GM, Nguyen B, Rhee E, et al. Endovascular treatment of the "failing to mature" arteriovenous fistula. *Clin J Am Soc Nephrol.* 2006;1:275-280.
17. Faiyaz R, Abreo K, Zaman F, et al. Salvage of poorly developed arteriovenous fistulae with percutaneous ligation of accessory veins. *Am J Kidney Dis.* 2002;39:824-827.
18. Turmel-Rodrigues L, Boutin JM, Camiade C, et al. Percutaneous dilation of the radial artery in nonmaturing autogenous radial-cephalic fistulas for hemodialysis. *Nephrol Dial Transplant.* 2009;24:3782-3788.
19. Miller GA, Goel N, Khariton A, et al. Aggressive approach to salvage non-maturing arteriovenous fistulae: a retrospective study with follow-up. *J Vasc Access.* 2009;10:183-191.
20. Goel N, Miller GA, Jotwani MC, et al. Minimally Invasive Limited Ligation Endoluminal-Assisted Revision (MILLER) for treatment of dialysis access-associated steal syndrome. *Kidney Int.* 2006;70:765-770.
21. Miller GA, Khariton K, Kardos SV, et al. Flow interruption of the distal radial artery: treatment for finger ischemia in a matured radiocephalic AVF. *J Vasc Access.* 2009;10:58-63.
22. Miller GA, Goel N, Friedman A, et al. The MILLER banding procedure is an effective method for treating dialysis-associated steal syndrome. *Kidney Int.* 2010;77:359-366.
23. Roy-Chaudhury P, Spergel LM, Besarab A, et al. Biology of arteriovenous fistula failure. *J Nephrol.* 2007;20:150-163.