Endovascular Therapies for Hemodialysis Access: Case Presentations of Salvage, Surgical Maturation, and Maintenance

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**ABSTRACT:** Arteriovenous (AV) access is a field in vascular interventional surgery that has undergone much evolution. Today many AV access sites are carefully monitored and facilitated, maintained, and salvaged through endovascular techniques. This enables the physician and patient to get significantly more use out of each access site created. This article presents the development of the endovascular field of access surgery. We also present illustrative cases that demonstrate examples of using such techniques in our practice.

**GUIDELINES FOR HEMODIALYSIS**

As life expectancy increases and the incidence of diabetes and hypertension grows, a greater number of patients are diagnosed with advanced chronic kidney disease. Chronic kidney disease eventually evolves into end-stage renal disease (ESRD) necessitating placement of permanent hemodialysis access. Permanent dialysis access of arteriovenous connection has been introduced and implemented since the 1960s. According to the National Kidney Foundation-Kidney Dialysis Outcomes Quality Initiative (NKF-KDOQI) and Society of Vascular Surgery (SVS) guidelines, it is recommended that patients be referred for permanent vascular dialysis access when creatinine clearance is less than 25 mL/min. Arteriovenous fistula (AVF) access has been the dialysis modality of choice over arteriovenous graft (AVG) placement when suitable vascular anatomy permits.

**ACCESS FAILURE, MATURATION, MAINTENANCE, AND SALVAGE**

The primary causes for dialysis access failure include poor inflow by arterial anastomotic failure, poor outflow due to central venous stenosis, small artery or vein preventing adequate volume of blood from circulating through the fistula, and collateral veins stealing blood from the primary vein. The minimal diameter of arteries and veins for access creation is 2 mm and 2 mm to 3 mm, respectively. Historically, many fistulas that have failed initial cannulation were
either abandoned or surgically revised. This resulted in numerous procedures throughout the lifetime of the patient to maintain dialysis access.

As the field of access surgery has evolved to better understand the causes for fistula and graft failures, the methods of treating dialysis problems have become less invasive, more aggressive, and increasingly sophisticated. Initiatives of access salvage, access maintenance, and fistula maturation have become more common concepts in hemodialysis. Fistula salvage refers to transforming nonmaturing or thrombosed fistulae to functional fistulae. Surgical maturation refers to decreasing the maturation time for fistulae to become usable with endovascular therapies. Finally, maintenance is described as prolonging patency rates of dysfunctional but patent fistulae. Arteriovenous fistula abandonment appears to be twice as costly as salvage of thrombosis with potential expenses per patient–month of $707 vs $375.4 One of the main factors that contributes to late access failure is intimal hyperplasia. This is caused by activation of macrophages and release of chemotactic agents, including platelet-derived growth factor, transforming growth factor beta, and angiotensin II, all of which promote migration of smooth muscle cells.4

**PERCUTANEOUS VASCULAR INTERVENTION OF FAILING ACCESS**

The earliest attempts at vascular access site salvage were described in 1984 study, where 8 of 10 balloon angioplasties were described as outright failures and the authors concluded that percutaneous transluminal angioplasty had a very limited role as an access site salvage procedure in AV grafts.5 Angioplasty was later combined with thrombolytic infusion in completely thrombosed AVFs and AVGs with 78% primary patency at 3 months and 36% primary patency at 9 months.6,7 In lesions that are stenosed, the median recurrence rate is 11 months in fistulas and 5 months in grafts, and they had a 72% patency at 6 months and 32% patency at 12 months.8 When no lesions within the vein are visualized, then the cause of fistula failure may be arterial stenosis. Angioplasty may be safely performed on the brachial artery to a primary patency rate of 83% at 1 year and 74% at 2 years. Forearm arterial access angioplasty is to be avoided in lesions in very distal extremities.9 Endovascular placement of stents was implemented for lesions resistant to balloon angioplasty with primary patency of 100% at 6.2 months as described by Hood et al.10 Patency of failing AV grafts was followed for a longer timeframe with the use of Viabahn stents by Davila Santini et al, with 94.7% 6- and 12-month patency, and 82.1% 18-, 24- and 36-month patency.11 The combination of performing AVF angioplasty with ligation of accessory venous side branches that can steal direct venous flow from arterialized veins can achieve access salvage in 82.5% to 100% of fistulas that fail to develop with 84% continued function at 3 months, 72% at 6 months, and 68% at 12 months.12,13 More recently, salvage of cephalic vein outflow has been described, including a totally percutaneous tunneled bypass using stent grafts in the basilic vein outflow with good intermediate follow-up results.14

**FISTULA SURVEILLANCE AND MATURATION**

Monitoring the progress of fistula maturation was traditionally clinically assessed with adequacy of thrill
and bruit over an enlarged vein. The use of ultrasound duplex measurement of blood flows >700-800 cc/min may effectively predict successful AVF maturation.\textsuperscript{14,15} Another study found a significant reduction in placement of central venous dialysis catheters with use of a surveillance program based on clinical and duplex ultrasound every 3 months, followed by fistulogram for stenosis compared to clinical and hemodynamic assessment in cases of dysfunction.\textsuperscript{16} Frequently access must be serially maintained with follow-up fistulograms and interventions in order to preserve patency. Falk analyzed 154 fistulas and determined that 3.3 procedures per fistula and 1.75 procedures per year must be performed in mature fistulas to maintain patency. These procedures included arterial and venous angioplasty, ligation of venous side branches, thrombectomy, and/or banding. The primary patency rate at 1 year was 64\% while secondary patency was 68\%.\textsuperscript{17}

The concept of serial dilations, known as balloon angioplasty maturation, may be used to increase the size of AVFs. Miller et al performed thrombectomy with angioplasty of 140 immature thrombosed fistulas. Average maturation time, defined as from thrombectomy to maturation for dialysis, was 46.4 days with an average of 2.64 interventions per patient. Percutaneous salvage of fistulas costs $4,881 to $14,998 less than the abandonment and new creation of AV access.\textsuperscript{18} De Marco Garcia et al also achieved excellent function of AVF \textless 3 mm in \textlesssim 2 months’ duration in 96\% of patients.\textsuperscript{19} Some have advocated performing endovascular interventional procedures in an office setting under ultrasound guidance. Gorin et al describes a 93\% 90-day patency rate in 55 interventions where a fistula was failing or not maturing. The overall rate of perifistular hematoma was 11\%, with 3 cases of thrombosis of AVF. No patient required hospitalization or urgent surgical intervention.\textsuperscript{20}

**CASE PRESENTATIONS**

**Case 1**

A 62-year-old male with history of coronary artery disease, diabetes mellitus, hypertension, peripheral artery disease, and chronic renal insufficiency predialysis underwent left radiocephalic end-to-side arteriovenous fistula. Intraoperative ultrasound demonstrated a radial artery with high take-off at the axilla. The radial artery was densely calcified, measuring 3.5 mm above the elbow, and was poorly visualized below the elbow due to calcification. Exploration of the radial artery at the wrist demonstrated a 2.0 mm calcified artery that was deemed marginal but usable for radiocephalic fistula creation. The cephalic vein, which measured 3.0 mm on ultrasound, was dilated to 3.5 mm intraoperatively prior to AVF creation. Excellent flow was established at the conclusion of the AVF creation. Two months postoperatively, the proximal fistula measured 4 mm to 5 mm by ultrasound. Good bruit and thrill were present over proximal AVF, but were weak in the distal AVF. A large 5 mm collateral vein was noted at the posterior forearm that appeared to be stealing flow from the true cephalic outflow, which measured 3.5 mm.

Two months after initial AVF creation, surgical ligation of the large collateral branch was performed to divert flow back to the primary cephalic vein. On ultrasound, the distal cephalic vein measured 3.5 mm to 4.0 mm. The patient was lost to follow-up thereafter and presented 15 months later, having progressed to
ESRD and receiving hemodialysis via a permcath. It was determined that some form of endovascular AVF intervention was performed at another institution. On physical exam, AVF contained a weak bruit and thrill. Ultrasound of the fistula measured the proximal cephalic vein at 5 mm to 6 mm. The middle portion of the vein was occluded with no flow or compressibility, whereas his distal cephalic vein reconstituted and measured <2 mm. The patient was then taken to the interventional suite for a fistulogram.

A micropuncture needle was used to cannulate the proximal vein in an antegrade direction. A 6 Fr short sheath was then placed. An initial fistulogram showed the proximal AVF and anastomosis to be patent without stenosis. The middle cephalic vein appeared completely occluded, whereas the distal cephalic vein above antecubital fossa reconstituted but was 1 mm to 2 mm in size (Figure 1). A combination of Glide-wire (Terumo) and Berenstein catheters was used to traverse the occluded segment. Five thousand units of heparin were administered and activated clotting time was maintained at >200. Mechanical thrombectomy was performed with 4 passes across the occluded segment (Figure 2).

**Figure 1.** Initial fistulogram showed proximal arteriovenous fistula and anastomosis to be patent without stenosis.

**Figure 2.** Catheters were used to traverse the occluded segment. Five thousand units of heparin were administered and activated clotting time was maintained at >200. Mechanical thrombectomy was performed with 4 passes across the occluded segment.
Balloon angioplasty was then performed to 6 mm at the previously thrombosed stenotic vein segment (Figure 3). In addition, the cephalic outflow above the antecubital fossa was noted to still be occluded. Additional Angiojet mechanical thrombectomy was performed, revealing a diminutively sized 1 mm to 2 mm cephalic outflow above the antecubital fossa (Figure 4). Additional angioplasty was performed on the small outflow vein to a final size of 6 mm. The central venogram demonstrated no residual stenosis (Figure 5).

Excellent thrill and bruit were demonstrated at completion of the procedure throughout the cephalic vein. At 1 week postoperative visit, physical exam revealed excellent bruit and thrill throughout the AVF. The cephalic vein measured 5.6 mm to 7.2 mm throughout the forearm and upper arm on ultrasound. There was no evidence of residual stenosis present in the fistula (Figure 6).

The patient was seen in the office 1 week later and cleared for dialysis via the fistula. The fistula was cannulated 2 weeks after the date of fistulogram and the Permcat (Covidien) was removed shortly thereafter.

Case 2

A 72-year-old male with chronic renal insufficiency and stage 4 chronic kidney disease had previously undergone a radiocephalic AVF. Two months prior to presentation, he was noted to have a diminishing thrill over his fistula on follow-up. An elective fistulogram was scheduled for salvage of the access site. On the date of the fistulogram, a bruit was no longer present and the fistula was noted to be occluded. After access of the cephalic vein was obtained, a fistulogram was
performed, followed by Angiojet mechanical thrombectomy of the occluded cephalic vein (Figure 7). This was followed by angioplasty with a 6 mm compliant balloon (Figure 8). Further angioplasty was performed on a persistent stenotic segment using a 6 mm noncompliant balloon with resolution of stenosis and complete restoration of flow (Figure 9).

**Case 3**

An 82-year-old female with a history of ESRD had undergone a right brachiocephalic AVF. She had multiple subsequent interventions for central outflow stenosis. The patient returned to the office with worsening swelling of the arm. An initial fistulogram demonstrated severe central venous stenosis. Angioplasty was performed with an 8 mm noncompliant balloon (Figure 10). Post dilation imaging revealed excellent results (Figure 11).

**Case 4**

A 73-year-old male with stage 4 chronic kidney disease had previously received a brachiobasilic AVF. On follow-up, he was noted to have a persistent massively
swollen left arm. An initial fistulogram demonstrated central venous outflow stenosis (Figure 12). Angioplasty was performed on the lesion (Figure 13) and a post dilation fistulogram demonstrated resolution in the outlet obstruction stenosis (Figure 14).

Case 5

An 85-year-old male with ESRD had a brachiobasilic straight AVG previously placed. Prior intervention necessitated placement of a covered stent for outflow stenosis. He presented to the office with occlusion of his AVG access. Initial fistulogram confirmed occlusion of the AVG (Figure 15). A Glidewire was used to traverse the occluded graft and outflow vein after access was gained via a direct brachial artery puncture. Angiojet mechanical thrombectomy was then performed to reestablish access patency. Angioplasty
was performed on the graft and outflow brachial vein (Figure 16). Imaging post procedure showed excellent flow through the fistula (Figure 17).

**PRACTICE PATTERNS AND CONCLUSIONS**

After successful endovascular salvage of the failing or thrombosed AV fistula, our patients are returned to the care of their nephrologists, who will routinely obtain monthly maintenance flow rates on dialysis. If these measurements are suggestive of a failing fistula, they will be referred back for evaluation and reintervention. Generally, values less than 400-500 mL/min necessitate vascular surgical consultation and a fistulogram based on the KDOQI guidelines.

However, patients who are deemed high risk for
recurrence of fistula failure, as evidenced by multiple repeat interventions in the past, will be followed much more closely by our vascular surgery service. These patients will return every 3 months for routine physical examination, careful questioning regarding the recent history of their access function, and a duplex ultrasound performed directly by the vascular surgeon. We typically will look for evidence of recurrent stenosis based on axial diameter measurements of the fistula flow lumen. Based on these findings, the decision will be made for reintervention if needed. In patients with recalcitrant stenosis who have had multiple interventions with angioplasty, we tend to use covered self-expanding stents such as Fluency (Bard Peripheral Vascular) for treatment.

Hemodialysis access is a growing and exciting field that has seen many advances. Careful patient selection...
is necessary for placement of permanent dialysis access with preference of fistula over graft. After completion of the procedure, it is essential to continue to regularly monitor the maturation of the access site. Multiple techniques may be used to accelerate maturation of an AVF. After successful cannulation of the fistula or graft, it is essential to be aware of potential stenosis from intimal hyperplasia over time that may cause dysfunctional flow. Multiple endovascular methods, including thrombectomy, angioplasty, and stent placement, may be used to salvage a failing access.

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