Percutaneous Salvage of Thrombosed Immature Arteriovenous Fistulas

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ABSTRACT

Thrombosed immature fistulas have historically been considered unsalvageable. However, advances in procedure and balloon catheter technologies have expanded the scope of endovascular treatments. This study investigates the efficacy, functionality, and cost associated with the use of percutaneous techniques for the salvage of thrombosed immature fistulas. Over a 2-year period and from a population of 18,000 patients on hemodialysis, 140 consecutive patients with thrombosed immature fistulas underwent attempts at salvage via thrombectomy procedures. All fistulas had thrombosed following access creation and had never been used for hemodialysis. Multiple approaches were utilized to gain access to the fistula, including trans-fistula cannulation, distal arterial puncture, and proximal retrograde venous access. Thrombectomy was performed via balloon maceration and aspiration. Accelerated maturation was achieved through sequential angioplasty of diffusely stenotic veins and elimination of competing branch vessels. Primary access, primary assisted, and secondary access patencies were calculated at 3, 6, 12, and 24 months. A cost analysis was performed based on procedure statistics and the 2009 Medicare reimbursement schedule and compared with data from the 2009 United States Renal Data Survey. Thrombectomy was successful in 119 (85%) immature clotted fistulas, and hemodialysis adequacy was achieved in 111 (79%) fistulas. The average maturation time from thrombectomy to cannulation for dialysis was 46.4 days, with an average of 2.64 interventions per patient. There were 5 (3.5%) cases of angioplasty-induced rupture, all of which were treated with stent placement. Clinically significant pseudoaneurysm formation occurred in 4 (2.8%) patients. At 12 months, secondary access patency of salvaged accesses was 90%. Based on 2009 Medicare outpatient billing rates per patient per initial access-year and the maturation times observed in the New York area, percutaneous salvage of thrombosed immature fistulas costs $4881 to $14,998 less than access abandonment and new access creation. Endovascular techniques can be used for the salvage of thrombosed nonmaturing fistulas. When analyzed within the initial access-year, this approach yields significant cost savings over access abandonment.

Throughout the 1980s and early 1990s, a favorable reimbursement climate and ease of surgical placement led to a high incidence and prevalence of the arteriovenous graft. However, the late 1990s saw the resurgence of the native vein fistula after its higher durability, lower long-term costs, and lower rates of infections and complications were demonstrated (1).

As the Centers for Medicare and Medicaid Services recognized the clinical and economic advantages of arteriovenous fistulas (AVFs), the Kidney/Dialysis Outcomes Quality Initiative (K/DOQI) 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 38–60% (4–6) compared with 15–23% in grafts (6–8). Because this represents the major shortcoming of this type of vascular access (1,7), improvements in techniques to salvage occluded fistulas are key to increasing their prevalence.

Although endovascular techniques have previously been used to salvage nonmaturing fistulas, thrombosed immature fistulas have almost always been excluded from prior studies because of poor technical success rates and low primary patency (9–12). Additionally, in order for an occluded AVF to achieve clinical usefulness, these methods often require multiple interventions (9,11,13), leading some health care payers to attempt to limit reimbursement for percutaneous treatment (Medicare LCD #DL30737V14). In comparison with prolonged hemodialysis catheter use while awaiting surgical revision and maturation of a new AVF, the timeliness of these salvage procedures offers a significant cost savings. This is the first study to specifically

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Short Summary: This is a large-scale study of the maturation of thrombosed immature fistulas through percutaneous techniques. The results show that endovascular salvage of thrombosed immature fistulas is feasible, safe, and cost-effective.

Seminars in Dialysis—2011
DOI: 10.1111/j.1525-139X.2011.00846.x

investigate the percutaneous salvage of occluded immature fistulas that had never been used for hemodialysis.

Methods

Patient Population

This study consisted of 148 consecutive patients (99 men and 49 women) with thrombosed, nonmaturing AVFs who were referred to 11 outpatient vascular access clinics (with 13 interventionalists) by surrounding dialysis centers with an estimated 18,000 patients between June 2007 and June 2009. The indication for all referrals was access thrombosis. All patients provided written informed consent. No IRB approval was required for this retrospective data analysis.

A fistula was considered thrombosed and immature if it thrombosed following access creation and was never used for dialysis. Patients with nonthrombosed immature fistulas were excluded from the study. The interventional procedures were performed by a team of interventional nephrologists, interventional radiologists, and vascular surgeons. Fistula maturity was defined as three consecutive successful hemodialysis sessions.

A retrospective analysis of patient records and digital images was conducted. All relevant patient data (including demographics, AVF sites, initial AVF diameter, number of maturation procedures, procedural complications, and AVF use at dialysis) were recorded for each patient.

Initial Evaluation

Ultrasound (Terason T3000, 5 MHz probe; Teratech Corp., Burlington, MA) was used to determine the diameter of the fistula at initial presentation. In 8/148 patients, the interventionalist considered percutaneous salvage to be impossible because of thrombosis of the inflow artery or inability to identify the arterial anastomosis and outflow vein through angiography or ultrasound. These patients were referred for new access placement.

Angiography

Angiography was performed with Oxilan intravenous contrast (Guerbet, Bloomington, IN); in patients with allergies to contrast media, carbon dioxide was used instead. Because the greatest challenge was gaining access to the fistula lumen, initial ultrasound evaluation determined whether a trans-fistula, trans-arterial, or proximal trans-venous approach would be used to gain access into the fistula lumen. An initial venogram was performed to assure patency of the venous outflow and central veins. An arteriogram was the first step in patients who required a radial artery approach.

Thrombectomy

One hundred and forty patients underwent attempts at thrombectomy. Because the thrombus burden was typically negligible, mechanical thrombectomy devices and thrombolytic agents were not necessary. Occluded veins were recanalized using 0.018-inch wires and Ultralow Profile Symmetry Balloons (Boston Scientific, Natick, MA). Dense thrombus (e.g., the "arterial plug" located at the anastomosis) was treated with balloon maceration thrombectomy. If no contraindication existed, 3000 units of heparin were administered.

Accesses >3 mm Diameter

Trans-Fistula Approach Using Antegrade and Retrograde Sheaths

The trans-fistula dual puncture opposing sheath approach was the preferred approach for fistulas >3 mm in diameter and most commonly used because of its familiarity and simplicity. Potential technical problems of this approach included lumen obstruction by the sheath during the procedure and hematoma formation at the puncture site during sheath removal. Because of these potential problems, alternative methods of access were sought in fistulas with diameters <3 mm.

Accesses <3 mm Diameter

Antegrade Trans-Arterial Access for Brescia–Cimino Fistulas

In fistulas with a 0.5–3 mm diameter, a distal radial artery puncture was the preferred initial puncture (provided the radial artery distal to the anastomosis was visible on ultrasound). Cannulation was first performed into the distal radial artery and a 4F catheter was placed. An initial arteriogram (GE OEC 9800) was performed to ensure alternate perfusion to the hand. A 4F or 5F sheath was placed into the artery. The arterial anastomosis was crossed using an angled diagnostic catheter with a 0.035-inch guidewire or a 0.018-inch V18 (Boston Scientific) wire. Once the body was cannulated, the wire and diagnostic catheter were navigated through the body of the fistula until a suitable basilic or brachial vein outflow was reached. The advantage of this approach is its convenience and the lack of risk for access point obstruction of fistula outflow.

Retrograde Trans-Venous Access into Brescia–Cimino Fistulas

The retrograde trans-venous approach was generally performed from a point in the mid-upper arm, where the veins were patent and had a diameter >3 mm. Wires and catheters were then navigated into the body of the fistula using both ultrasound and fluoroscopic techniques. Once the anastomosis was crossed, the wire was directed proximally into the radial artery and the thrombectomy procedure would then be initiated.

Angioplasty Dilatation

In some instances, it was necessary to control the inflow using manual compression or an occlusion balloon. Sequential balloon dilation was initiated starting with a 2-mm-diameter Symmetry balloon and upsized in 1-mm increments up to 6 mm at the first visit, in accordance with the Staged Balloon Angioplasty Maturation and flow rerouting techniques (9). The entire length of the fistula body was upsized using long length balloons (80–100 mm). The anastomosis and the radial artery proximal to the anastomosis were generally dilated last, but always required dilation and resistant lesions were frequently encountered. (The radial artery was never dilated to a diameter >4 mm.) Angioplasty was performed to 18 atmospheres of pressure, with immediate deflation of the balloon after full effacement of the lesion. Prolonged inflation (≥60 seconds) was only performed in cases of venous rupture. Flow was only restored to the fistula when the interventionalist was certain that any sites of extravasation had been adequately treated.

Collateral vessels that competed with the primary venous outflow were ligated or embolized with endovascular coils (Nestor, Cook, Bloomington, IN). Vessels were considered to be significant (3–8 mm diameter) and in need of treatment only if they had a persistent high-velocity imaged flow or a palpable thrill following angioplasty of the main fistula channel.

Once the fistula was dilated to 6 mm, the sheath was removed and hemostasis was achieved with 5 minutes of pressure followed by a small pressure dressing. Following the procedure, patients were typically administered a single dose of aspirin 81 mg and clopidogrel 150 mg to help decrease the risk of immediate rethrombosis.

Extravasation/Stent Placement

If angioplasty dilatation resulted in rupture, an inflated balloon was used to tamponade the region for 2 minutes. Extravasation that persisted following tamponade was treated with the placement of an uncovered stent (Protégé EverFlex; ev3, Plymouth, MN) or covered stent (Viabahn, Gore, Flagstaff, Arizona; Fluency, Bard Peripheral Vascular, Tempe, AZ; FLAIR, Bard Peripheral Vascular, Tempe, AZ).

Uncovered stents were used in low-pressure regions of the fistula; covered stents were deployed in regions of high pressure and/or tortuosity, or in situations where extravasation could not be controlled through uncovered stent placement.

Clinical Success

Clinical success was defined as the fistula being used for three consecutive successful hemodialysis sessions.

Follow-Up

A retrospective database was established, and follow-up data were collected to evaluate the longevity of the salvaged accesses. Following completion of the maturation process, patients were referred for a fistulagram by their dialysis center at first signs of fistula dysfunction, such as prolonged bleeding, high venous pressure, pulsatility, or difficult needle cannulation. All relevant data were obtained from chart reviews and patients who did not undergo additional procedures at our center were contacted by telephone for follow-up information. Death and kidney transplantation were considered to be the end of follow-up.

Complications

In accordance with the Society of Interventional Radiology (SIR) criteria, major complications are defined as those that required hospitalization, caused permanent adverse sequelae, and death. Minor complications are defined as those that required nominal interventions and did not interfere with hemodialysis treatment (14).

Statistical Analysis

Fistulas were categorized as brachial-cephalic (BCF), brachial-basilic (BBF), or forearm (FF). Four untransposed and 20 transposed basilic vein fistulas comprised the BBF group, and one ulnar-basilic fistula was combined with 54 radial-cephalic fistulas to form the FF group.

Because the treatment consisted of a series of interventions, rather than a single intervention, all patency measures were considered to begin with the last intervention for fistula maturation. Primary access patency ended with the first intervention within the access, after successful maturation was achieved. Primary assisted patency ended with the first percutaneous thrombectomy or surgical revision. Secondary access patency ended with surgical revision or access abandonment. One-way ANOVA tests were performed to evaluate outcome differences between the three fistula types. Unpaired *t*-tests were performed to determine whether significant outcome differences existed between any two patient groups. A p-value <0.05 was considered significant.

Cost Analysis

An analysis of the cost per initial patient-year of this fistula maturation method and the alternative of surgical revision was performed based on the maturation statistics of the analyzed fistulas, Medicare reimbursement rates, and data from the 2009 United States Renal Data System (USRDS) survey. According to the USRDS, the total cost of maintaining a patient on hemodialysis was $55,112 for an arteriovenous fistula and $75,345 for a catheter (15). In accordance with K/DOQI guidelines, a period of 3 months was chosen as the duration of catheter usage following access placement (2).

The cost of the maturation process was calculated based on 2009 Medicare reimbursement rates. The procedures included access into the fistula with imaging (CPT code 36147 = $957), angioplasty (CPT codes 35476 and 75978 = $2344), stent placement (CPT codes 37205 and 75960 = $5457), embolization via endovascular coil placement (CPT codes 37204 and 75894 = $1058), and thrombectomy (CPT code 36870 = $2233).

The costs were calculated as follows:
Percutaneous salvage:

Cost of maturation process based on presented data and Medicare reimbursement rates
+ Cost of catheter usage during average maturation period
±(1 year—average maturation time) × (average cost of a fistula per patient-year according to USRDS)
Total cost per patient for the first year following the initial referral for the percutaneous route

New access placement (assuming maturation time of 3 months):

Cost of surgery
+ Cost of 3 months of catheter usage according to USRDS data
±Cost of 9 months of fistula usage according to USRDS data
Total cost per patient for the first year following the initial referral for the surgical route

New access placement (assuming maturation time of 9 months):

Cost of surgery
+ Cost of 9 months of catheter usage according to USRDS data
±Cost of 3 months of fistula usage according to USRDS data
Total cost per patient for the first year following the initial referral for the surgical route

Results

Patient Demographics

The average patient age at initial presentation was 63.6 years (range, 17–88). Sixty-one percent of patients were diabetic and 67% were men. The average fistula age at initial presentation was 5.6 months. The average mid-body fistula diameter was 1.5 mm; the average length of the thrombosed vein segment was 15 cm (Table 1). Neither initial vein diameter nor thrombosed segment length correlated with the technical success of the thrombectomy.

TABLE 1. Patient demographics

Age—mean, range (years)	63.6 (17–88)
Male gender (%)	67
Diabetes mellitus (%)	61
Hypertension (%)	91
Fistula Type, *n* (%)	
Radial-cephalic	69 (49)
Brachial-cephalic	39 (28)
Brachial-basilic	4 (3)
Brachial-transposed basilic	26 (19)
Brachial-antecubital	1 (1)
Ulnar-basilic	1 (1)
Average fistula age at time of first intervention (months)	5.6
Thrombosis duration—mean, range (weeks)	3 (1–12)
Average mid-body fistula diameter prior to initial intervention (mm)	1.5
Length of thrombosed vein segment—mean, range (cm)	15 (5–35)

Thrombectomy Statistics

Of the 140 fistulas that were intervened upon, 119 (85%) were successfully declotted. The 21 thrombectomy failures were caused by occlusions that could not be traversed.

When an occluded fistula vein had a diffusely narrow outflow that could not be visualized through ultrasound or angiography, but did have a detectable arterial anastomosis, the interventionalist used a radial artery puncture to gain access into the AVF lumen. In 22 cases, the thrombectomy was performed from a puncture into the radial artery distal to the anastomosis. Fifteen of these attempts were successful. The seven failures resulted from an inability to cross the anastomosis.

Of the 119 successful thrombectomies, 14 (10%) required stent placement for venous rupture or elastic recoil; no arterial ruptures were encountered. Eight BBFs required stent placement, with seven being placed at the axillary vein swing site (two covered, five uncovered); six BCFs required stent placement, with three uncovered stents being placed in the cephalic vein arch (Table 2). A significantly smaller number of stents was required by FFs when compared with both BCFs ($p < 0.05$) and BBFs ($p < 0.05$).

Maturation Statistics

One hundred and eleven (79%) fistulas were matured through sequential angioplasty procedures and became usable for hemodialysis (clinical success), while eight fistulas could not be matured owing to complications of a high-origin radial artery ($n = 3$) or diffusely narrow inflow artery with a diameter <2 mm ($n = 5$). Three patients were lost to follow-up, and information was collected for the remaining 108 patients (Fig. 1).

Following the thrombectomy, an average of 2.6 angioplasty procedures, 0.34 stent placements, and 0.22 coil embolizations were required for each access to mature. During the maturation period, stents were placed in seven patients with FFs, 11 patients with BCFs, and 12 patients with BBFs. The average maturation time was 46.4 days, with 2.64 interventions required; no significant differences were observed between the three fistula groups.

TABLE 2. Thrombectomy statistics for 108 fistulas

	BBF ($n = 24$)	BCF ($n = 29$)	FF ($n = 55$)
Percentage of fistulas requiring arterial angioplasty	2	3	24
Percentage of fistulas requiring angioplasty of the anastomosis	4	21	54
Percentage of fistulas with venous perforation or elastic recoil requiring stent placement	33	21	2

AVF, arteriovenous fistula; BBF, brachiobasilic fistula; BCF, brachiocephalic fistula; FF, forearm fistula.

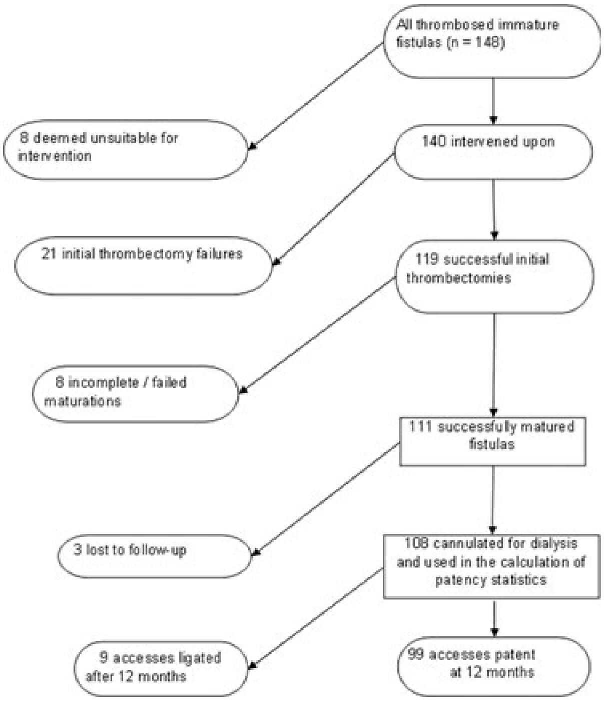

Fig. 1. Patient attrition flowchart.

Forearm fistulas were significantly more likely than upper arm fistulas to require arterial angioplasty during the maturation process (3.88 vs. 0.58 per access-year, $p < 0.05$). Upper arm fistulas (BBFs and BCFs) required a significantly greater amount of stents than FF (43% vs. 13% of fistulas, $p < 0.05$).

Postmaturation Patency

Postmaturation maintenance required 2.78 interventions per access-year, including 0.52 thrombectomies per access-year. Fistula type did not affect the rate of thrombotic events ($F = 1.14, p = 0.32$).

Postmaturation primary access patency for all 108 fistulas at 3 months was 53% (Fig. 2). The primary assisted patency at 12 months was 59% (Fig. 3); the corresponding secondary access patency was 90% (Fig. 4). Table 3 provides a more detailed analysis of patency data.

Following maturation, FFs required fewer interventions per access-year (including thrombectomies) than upper arm fistulas ($p < 0.05$). Nevertheless, 12-month secondary patencies did not significantly vary with fistula type.

Complications

There were no major complications. Minor complications were comprised of five instances of angioplasty-induced rupture and eight instances of pseudoaneurysm formation (with two requiring treatment). All cases of rupture were successfully treated with the placement of a stent (three covered, two bare nitinol), and the two clinically significant pseudoaneurysms were successfully excluded through the placement of covered stents. None of these complications resulted in delay of the maturation process. There were no access-related infections during the maturation process.

Follow-Up

The average follow-up time was 12.8 months (range, 1–30). During the course of the study, three patients received kidney transplants and 10 patients expired; none of the deaths were access related. Pseudoaneurysms occurred in 10 patients during follow-up (at an average of 280 days postmaturation), with two requiring treatment (via placement of covered stents or 10-mm Nestor coils). No access-related infections occurred during the follow-up period.

Cost Analysis

Based on an average of one thrombectomy, 2.6 angioplasty procedures (with access into the fistula), 0.34 stent placements, and 0.22 coil embolizations required for each access to mature, the average cost of fistula salvage was \$12,904. The average cost of new access placement was determined to be \$15,359 within the New York area (16). The cost per patient per initial access-year was \$70,648 for percutaneous salvage vs. new access creation at \$75,529 (assuming subsequent maturation after 3 months) to \$85,646 (assuming subsequent maturation after 9 months).

Cost calculations:
Percutaneous salvage:

\$12,904 = cost of maturation process based on presented data and Medicare reimbursement rates
+\$9496 = cost of 46 days of catheter use during average maturation period
±\$48,166 = ([365–46 days of fistula use] ÷ 365) × (\$55,112 per patient per year cost of fistula)
\$70,566 = total cost per patient for the first year following the initial referral for the percutaneous route

New access placement (assuming maturation time of 3 months):

\$15,359 = cost of surgery
+\$18,836 = cost of 3 months of catheter usage according to USRDS data
±\$41,334 = cost of 9 months of fistula usage according to USRDS data
\$75,529 = total cost per patient for the first year following the initial referral for the surgical route

New access placement (assuming maturation time of 9 months):

\$15,359 = cost of surgery
+\$56,509 = cost of 9 months of catheter usage according to USRDS data
±\$13,778 = cost of 3 months of fistula usage according to USRDS data
\$85,646 = total cost per patient for the first year following the initial referral for the surgical route

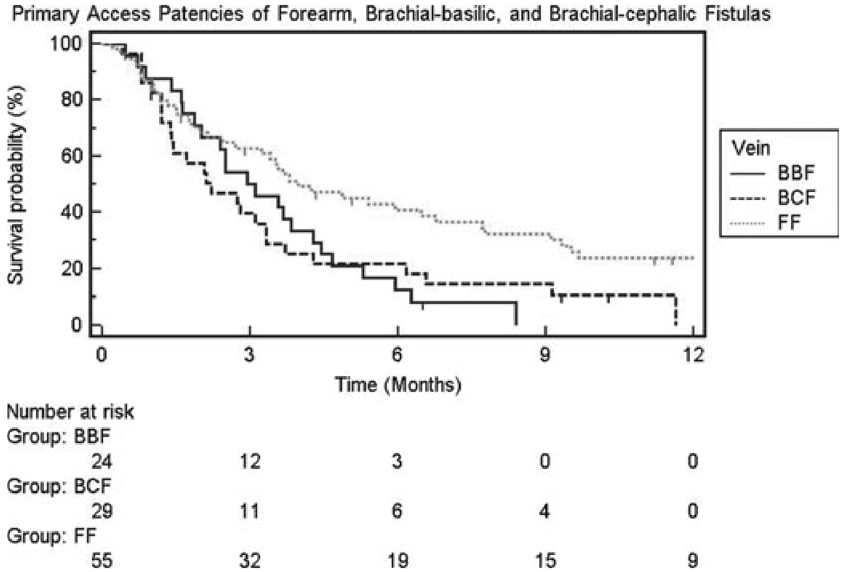

FIG. 2. Primary access patencies of forearm, brachial-basilic, and brachial-cephalic fistulas.

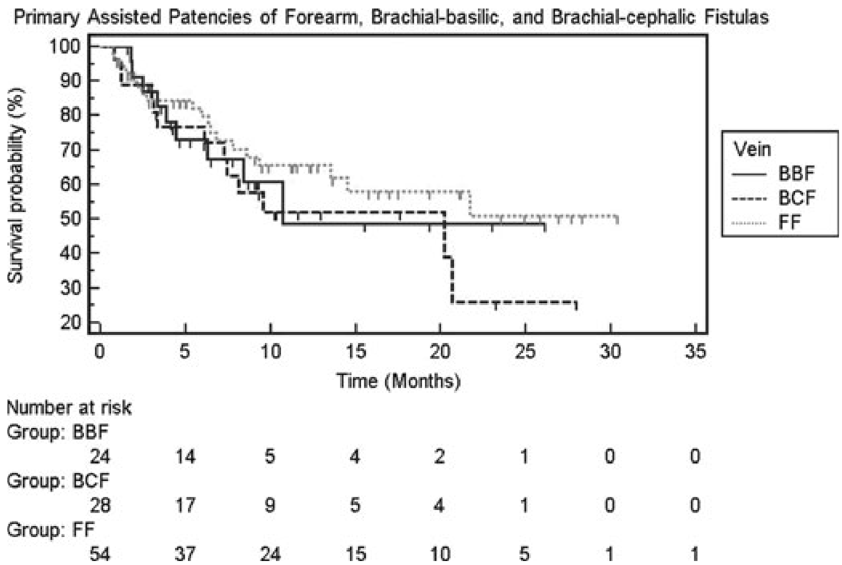

FIG. 3. Primary assisted patencies of forearm, brachial-basilic, and brachial-cephalic fistulas.

Discussion

Clinical Implications

In the United States, there are approximately 340,000 patients with end-stage renal disease who require routine hemodialysis as their renal replacement therapy, and 54.7% of these patients had an arteriovenous fistula as their primary vascular access as of January 2010 (17). The K-DOQI guidelines have prioritized increasing the prevalence of fistulas among vascular access types because of the lower rates of mortality and infection associated with them, as well as their lower cost per patient-year (18–21). As a result, fistula salvage not only preserves venous capital in patients, but also represents an important method of cost containment for the burgeoning hemodialysis population.

Large-scale fistula maturation studies have observed early (precannulation) failure rates of 38–60% (4–6). To date, only one study of fistula salvage has included thrombosed immature fistulas, with 17 fistulas successfully salvaged through endovascular techniques (12). Others have included a small portion of thrombosed immature fistulas, but failed to delineate their outcomes (13,22), or explicitly excluded such cases (9,23). The present study is comprised of fistulas that had never been used because they thrombosed before they were deemed suitable for hemodialysis.

The most common treatment for a thrombosed immature fistula has been abandonment and the creation of a new access. This not only extends the duration of central venous catheter usage, with the associated risks of bacteremia (7), but may not even increase the patient's likelihood of attaining a permanent vascular access. In particular, patients with poor vasculature may experience a recurrence of these problems once a new access is placed. In many instances, a nonmaturing thrombosed Brescia–Cimino fistula would be aban-

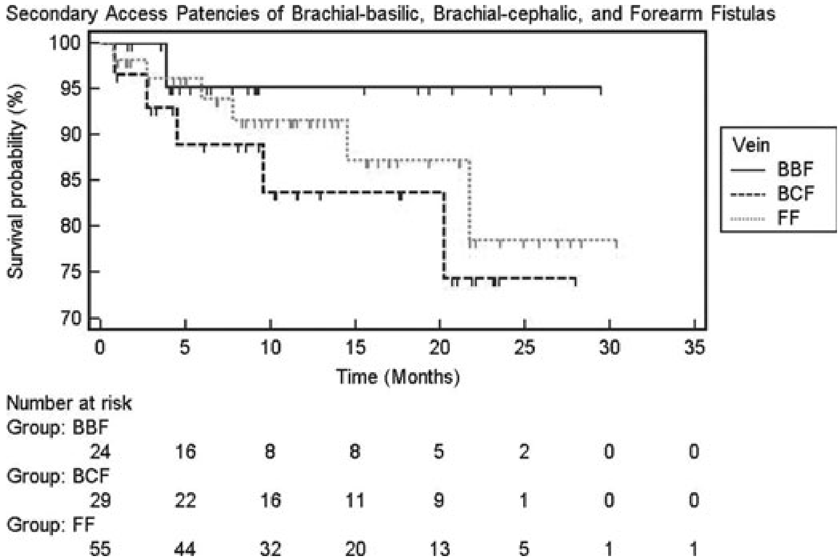

FIG. 4. Secondary access patencies of brachial-basilic, brachial-cephalic, and forearm fistulas.

TABLE 3. Follow-up statistics for 108 matured fistulas

	Time (months)	All AVFs (n = 108)	BBF (n = 24)	BCF (n = 29)	FF (n = 55)
Primary access patency	3	54%	50%	40%	63%
	6	29%	13%	22%	41%
Primary assisted patency	6	78%	73%	77%	80%
	12	59%	49%	52%	66%
Secondary access patency	12	90%	95%	84%	92%
	24	80%	95%	74%	79%
Postmaturation interventions per access-year		2.78	3.56	3.46	2.03
Postmaturation thrombectomies per access-year		0.52	0.64	0.72	0.35

AVF, arteriovenous fistula; BBF, brachiobasilic fistula; BCF, brachiocephalic fistula; FF, forearm fistula.

doned and replaced with an upper arm polytetrafluoroethylene graft.

Nonmaturation of fistulas stems from both arterial and venous pathologies. Previous studies have analyzed problems such as venous stenosis and collateral veins, or the role of small, insufficient arteries, in access dysfunction (10,12,24,25). We have found that both types of problems must be treated concomitantly to salvage occluded immature fistulas.

During the maturation process, FF were significantly more likely than upper arm fistulas to require arterial angioplasty ($p < 0.05$), which is to be expected given the smaller diameter of more distal arteries. Upper arm fistulas (BBFs and BCFs) required a significantly greater amount of stents than FF ($p < 0.05$), because of the development of axillary vein swing site and cephalic vein arch stenoses that were refractory to angioplasty. The overall number of interventions to achieve maturity did not significantly differ between the three fistula groups, rendering these salvage methods effective for all fistula types. However, FF had superior primary patency and required significantly fewer interventions to maintain secondary patency. We therefore readily suggest that this salvage technique be the preferred treatment for thrombosed immature Brescia–Cimino fistulas.

Upper arm fistulas required a significantly greater number of postmaturation interventions than FF. Although some may contend that salvaging a fistula which will require 3.46–3.56 maintenance interventions per access-year is worse than graft creation (at 1.8–5.3 interventions per access-year (7,8,26)), we note the absence of infection among salvaged fistulas (when compared with grafts, which have an infection rate of 6–22%(1)). Therefore, we believe our technique is the preferable option even for upper arm fistulas.

Our 79% rate of clinical success, along with a secondary access patency of 80% at 24 months, suggests that endovascular techniques can be successfully recruited for the salvage of thrombosed immature fistulas. Fistula maturation times have ranged from 1.5 to 4.9 months (5–7,9,27–29); our average maturation time was 46.4 days (1.55 months), pointing to another benefit of this approach as patient catheter days were reduced.

Economic Implications

Our treatment approach yields substantial cost savings. The average cost of the entire maturation process is $12,904 per fistula. Although this is approximately equivalent to the cost of new access placement ($15,359), when the costs associated with catheter use are included ($6279 vs. $4593 per patient-month for catheter and fistula use, respectively), the total costs per patient-year amount to $70,648 for the endovascular salvage approach and $75,529 for new access creation (30,31). Thus, even if the new fistula matures without any interventions 3 months after the surgery—which may occur in as few as 40% of cases (4)—the surgical approach will have cost $4881 more per patient-year than endovascular salvage. However, based on the referral patterns in our community and the resultant prolonged catheter use (which is typically about 9 months), we estimate the cost savings to be closer to $14,998 per patient during the initial patient-year.

The above cost analysis is predicated on a minimum catheter time of 3 months (90 days) because of a Medicare reimbursement policy that imposes a 90-day restriction on inpatient physician billing for repeat surgery on the same person (32). As this rule disincentivizes the rapid creation of a new fistula, physicians are unlikely to perform an additional access creation within that period, even if the present access is likely to fail. Therefore, given the current reimbursement guidelines, outpatient percutaneous fistula salvage procedures provide a significant cost savings to the US health care system.

Study Limitations

Although this study is limited by its retrospective nature, the large patient cohort and considerable follow-up time likely provide sufficient normalization of confounding variables. Nevertheless, prospective studies with more detailed measurements of thrombus amounts and locations, regular angiography, anastomotic configuration, preoperative vein diameter and other parameters would greatly improve our understanding of fistula maturation.

Acknowledgments

Michael Alesi, RT, and James Smith, RT, provided expert technical advice to make these procedures possible and successful.

Conflict of Interest

Gregg A. Miller, Wayne Hwang, Dean Preddie, Aleksandr Khariton, Yevgeny Savransky—None to declare.

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