Two-year cumulative patency of endovascular arteriovenous fistula

Gerald A Beathard1, Terry Litchfield2 and William C Jennings3

Abstract
Background and objectives: The recent advent of a device to create a proximal radial artery arteriovenous fistula using an endovascular approach to create the anastomosis represents a significant advance in dialysis access creation. This endovascular arteriovenous fistula offers the beneficial attributes of the proximal radial artery arteriovenous fistula while adding the advantages of avoiding a surgical procedure. The endovascular arteriovenous fistula can be created safely, functions well, has excellent patency, and has a high degree of patient satisfaction. The purpose of this study is to report the 2-year cumulative patency rate for a large multicenter cohort of endovascular arteriovenous fistula cases.

Design: An endovascular arteriovenous fistula was created in 105 patients using either local or regional anesthesia and conscious sedation. Patient data were obtained from each program’s electronic health record system. Data collection was truncated at 2 years postprocedure and used to calculate cumulative patency. Post-access creation patient satisfaction was assessed.

Results: A physiologically mature arteriovenous fistula (blood flow $\geq 500$ mL/min and a target vein internal diameter $\geq 4$ mm) was obtained in 98%. A clinically functional arteriovenous fistula (supporting two-needle dialysis according to the patient’s dialysis prescription) was demonstrated in 95%. Access failure resulting in the loss of access occurred in eight cases during the study period. The cumulative patency rate at 6, 12, 18, and 24 months was 97.1%, 93.9%, 93.9%, and 92.7%, respectively. The post-procedure patient evaluation emphasized a high level of patient satisfaction.

Conclusion: The proximal radial artery arteriovenous fistula created using an endovascular approach for the anastomosis is associated with excellent 2-year cumulative patency and is associated with a high level of patient satisfaction.

Keywords
arteriovenous fistula, dialysis access, arteriovenous fistula, endovascular arteriovenous fistula, percutaneous arteriovenous fistula, Ellipsys, proximal radial artery, hemodialysis

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Introduction
The goal of a dialysis vascular access is to provide reliable access to the circulation suitable for sustained clinical use with minimal complications associated with either its creation or its use. Of the alternatives available, an arteriovenous fistula (AVF) represents the best choice for most patients. The mature, clinically functional AVF is associated with lower morbidity and mortality, better patency rates, and a higher level of patient satisfaction and quality of life than other alternatives.1

Traditional dialysis access planning generally evaluates the possible creation of one of three AVF configurations: radial-cephalic, brachial-cephalic, or brachial-basilic. Patient selection is important because each of these have associated disadvantages. When several choices are possible based upon vascular mapping and physical examination, preference is given to using the forearm over the upper arm.2
Unfortunately, the forearm radial-cephalic AVF has a higher primary failure rate and shorter duration of patency than an AVF created in the upper arm, especially in the elderly patient. However, the incidence of dialysis access steal syndrome (DASS) and high-output cardiac failure is higher with an upper arm AVF. This increased incidence is attributed to the use of the brachial artery and the associated higher blood flow rate.

In order to increase the opportunities for the creation of an AVF, a variety of other configurations have been described. One of these is the proximal radial artery (PRA)-AVF. Although first described in 1977, until recent years, the PRA-AVF has been infrequently used, a problem likely due to unfamiliarity with this access option and its non-inclusion in common guidelines. Experience with the PRA-AVF has shown it to have a lower complication rate and a primary, assisted primary, and cumulative patency rates that are superior to the radial-cephalic AVF especially in elderly as well as pediatric patients. In addition, by using radial artery AVF inflow rather than from the brachial artery, there are lower risks of DASS, arm edema, high-output cardiac failure, the development of a “mega-fistula,” and idiopathic monomeric neuropathy. As a result, some surgeons have adopted this configuration as the first alternative in a patient in whom a radial-cephalic AVF is not feasible or where marginal vessels suggest a high likelihood of failure.

The recent advent of a device to create an endovascular AVF (enAVF) represents a significant advance in dialysis access creation. Although viewed as a new type of AVF, it is in reality a PRA-AVF in which the anastomosis is created in a unique manner using a novel endovascular device. As such, the enAVF has the beneficial attributes of the PRA-AVF while adding the advantages of avoiding the trauma of surgery by allowing a percutaneous approach performed under local/regional anesthesia. In addition, the location of the anastomosis and lack of an incision significantly expands the cannulation zone of the access in many patients.

Previous reports have documented the safety of this technique for creating an anastomosis resulting in a functional dialysis access with excellent primary and cumulative patency rates and a high degree of patient satisfaction. The purpose of this study is to report the 2-year cumulative patency rate for a large multicenter cohort of enAVF cases. In addition, patient satisfaction with this approach to creation of an access was further examined.

**Methods**

This was a retrospective analysis of data generated by five vascular access programs in the United States. This study obtained prior approval from the institutional review board and was in accordance with the Declaration of Helsinki. Individual informed consent was not required by the institutional review board since this was a retrospective study.

After a vascular evaluation for suitability, all patients had an enAVF created using the using the Ellipsys® Vascular Access System (Avenu Medical, San Juan Capistrano, CA) as has been previously described. This is a thermal resistance device consisting of a single venous access catheter. Using either local or regional anesthesia and conscious sedation, the catheter was introduced retrograde over a guide wire through a single cannulation of either the cephalic or median cubital vein at the elbow. The device was then advanced through the deep communicating vein and into the adjacent PRA. The Ellipsys enAVF procedures were completed using only ultrasound guidance without radiation exposure. An anastomosis was created using the device to apply pressure and heat to securely fuse the deep communicating vein and PRA in the antecubital fossa where these two anatomic structures are adjacent. Following the creation of the anastomosis, it and the deep communicating vein were dilated with a 5 mm angioplasty balloon under ultrasound guidance as a planned secondary procedure. Currently, the balloon dilatation of the anastomosis is completed immediately as a routine part of the primary procedure. The definition for a physiologically mature AVF used in this study was a brachial artery blood flow ≥500 mL/min and a target vein internal diameter ≥4 mm. A clinically functional AVF was defined as an access capable of supporting two-needle dialysis according to the patient’s dialysis prescription.

Patient data were obtained from each program’s electronic health record system using a specially created data collection form. Random audits were conducted to assure complete and accurate retrieval of data. The electronic medical record contained patient data entered by the facility creating the access as well as that entered at the dialysis treatment facility by the facility staff. Data collection was truncated at 2 years postprocedure (730 days).

A post-access creation patient satisfaction assessment survey was developed by a trained research assistant/patient advocate and mailed to each patient 2 years (plus or minus 30 days) after enAVF creation. This included a five-level Likert-type scale with 1 being “Excellent” and 5 being “Poor” as well as questions that could be answered yes or no. At the end of the study period, the survey was mailed to all patients still active in the study. In addition, a patient engagement focus group which included patients who were from 1½ to 2½ years after enAVF creation was convened and led by an experienced facilitator to further explore patient satisfaction.

Summary statistics for continuous variables were reported as a mean, 95% confidence interval (CI), and a range. The cumulative patency rate was determined using Kaplan–Meier life table analysis according to standard definitions. Transplantation, loss to follow-up, and patient death were considered to be censored events. MedCalc Statistical Software version 16.8 (MedCalc Software bvba,
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Ostend, Belgium; https://www.medcalc.org; 2016) was used for all analyses.

Results

A total of 105 patients were entered into this study. This number included all cases of an enA VF created at these five centers during a time period that would allow for a 2-year follow-up. Patient demographics are shown in Table 1. The mean age of the cohort was 56.2 years with the range of 30–80 years. Almost three-fourths were male, and the majority of the patients were at least moderately obese (median body mass index (BMI) = 30.1). Patient demographics other than those reported were not collected.

The criteria for use of the enA VF (physiologically functional A VF) was met in 103 patients and was used to provide two-needle dialysis in all except three of these cases. In one case, the patient did not reach the point of requiring renal replacement therapy during the study period. In two cases, the patients were receiving peritoneal dialysis and the arteriovenous access was created as a backup. Each of these three individuals had a physiologically functional A VF.

Access failure resulting in the loss of access occurred in eight cases during the study period. There were two cases (1.9%) of primary failure and six instances (5.7%) of late failure occurring at a mean of 317 days (95% CI = 75–327, range = 35–603) following creation of the enAVF. A total of 18 patients (17%) died with a functioning A VF during the course of the observation period from causes unrelated to the access procedure. The duration of function in these 18 cases had a mean of 353 days (95% CI = 252–453, range = 28–669).

Discussion

The optimal vascular access for dialysis is a clinically functional AVF.\(^1\)\(^2\)\(^3\)\(^4\)\(^5\) However, the key term is \textit{clinically functional}. Unfortunately, a large percentage of surgically created AVFs experience either primary failure or failure
to mature (FTM).26,27 Although many of these cases can be salvaged,28–30 in between primary surgical failures and maturation failures, 39% of AVFs placed between June 2014 and May 2016 in the United States were unsuccessful.31 Many of these early AVF failures are ultimately salvaged, but frequently require more than one procedure to become clinically usable.32 In addition, the AVF successfully treated for FTM has been shown to have a shortened primary patency rate in comparison to an AVF that matures without intervention making repetitive interventions necessary for continued clinical use.33–35 In addition, failure of AVF function results in an escalating cost.36

The most common lesion resulting in FTM is stenosis of the juxta-anastomotic segment of the AVF with an overall incidence ranging from 43% to 55%. It has been reported to occur in 54%–77% of dysfunctional forearm AVFs and 46%–56% of those in the upper arm.37 Although it seems apparent that there is an association with either the way the anastomosis is created or its configuration that results in vascular injury culminating in juxta-anastomotic stenosis, the exact etiology is not clear. Possible mediators of vascular injury in this setting include (1) direct hemodynamic injury due to non-laminar flow and oscillatory wall shear stress related to the anatomical configuration of the anastomosis, (2) surgical injury from surgical site inflammatory process, and (3) angulation and spiraling of the peri-anastomotic venous segment at the time of surgical AVF creation.38–41

These data make it clear that there is a need for innovation in AVF creation. It has been proposed that surgical techniques that minimize venous dissection might improve fistula maturation and access patency.39,41,42 These techniques have dealt primarily with variations in the configuration of either the vein39 or the artery41 used in creating the anastomosis and have shown a significant decrease in FTM and an improvement in AVF maturation. This study demonstrates that using this novel technique to create the anastomosis which avoids surgical trauma and vessel manipulation can result in a marked enhancement in the creation of a clinically functional dialysis access with the attributes of a PRA-AVF. The enAVF creates an anastomosis between the adjacent deep communicating vein and PRA, avoiding vessel mobilization, rotation of vein to artery, and the opportunity for technical misadventure. The vessels remain in their native position. Moderate flow and lower pressure produced by these PRA enAVFs also avoid the substantial risks associated with a brachial artery anastomosis.8,10–13

Table 2. Patient satisfaction survey.

| Variable                        | Excellent (%) | Very (%) | Good (%) | Good (%) | Fair (%) |
|---------------------------------|---------------|----------|----------|----------|----------|
| Level of pain with procedure    | 74            | 21       | 5        | 0        | 0        |
| Perception of technical ease    | 47            | 16       | 16       | 21       | 0        |
| demonstrated by operator        |               |          |          |          |          |
| Overall satisfaction with procedure | 69          | 24       | 4        | 3        | 0        |
| Comparison with previous procedure | 10          | 19       | 68       | 3        | 0        |

Although an AVF is the optimal vascular access, not all AVFs are equal. In a meta-analysis involving 200 studies reporting on 875,269 vascular accesses,1 an upper arm AVF (brachial-basilic or brachial-cephalic) had the best primary patency. The primary patency for a radial-cephalic AVF was only slightly better than an arteriovenous graft (AVG) in males and not as good as an AVG in females. The PRA-AVF was not included in these studies. In spite of multiple reports of successful outcomes with the PRA-AVF,10,11,16–20 this option for AVF configuration is frequently overlooked as an alternative. The brachial-cephalic AVF (BCA VF) is often the first option recommended for a patient in whom a radial-cephalic AVF is not possible. However, in a systematic review of 10 studies involving 1,310 patients with a PRA-AVF,11 the primary failure rate, primary patency, and cumulative patency at 1 and 2 years were better than was reported in a large series of cases for either the standard forearm or upper arm AVF.43 In a study which compared 56 cases of BCAVF with 50 patients having a PRA-AVF with a mean follow-up period of 1.8 years,20 no differences in the percentage of the two access types being successfully used for dialysis treatment were noted and primary, primary assisted, and cumulative patency rates were similar between the two groups. However, complications such as arm swelling, DASS, and the development of aneurysms were significantly less common in the PRA-AVF group. It was suggested that the prevalence of these complications was less after creation of a PRA-AVF because the radial artery provides a lower blood flow rate. This is a particularly attractive characteristic of this access, especially in the elderly patient.44

In previous reports, patency advantages of the enAVF in comparison to a surgical AVF have been documented.21–23 In the Pivotal Multicenter Ellipsys trial,21 a primary failure rate of 5% was reported and cumulative patency for 107 cases was 92.3%; however, because some patients had not yet required renal replacement therapy at the end of the study period, only 88% of cases were using the access for dialysis. In another study involving 34 cases,22 the primary failure rate was 3% (1 case). At 6 weeks, all fistulas had been used or were ready for use by clinical or ultrasound examination (vein diameter ≥6 mm for a 10 cm length and blood flow ≥600 mL/min). Access blood flow (measured at the brachial artery) at a mean of 669 mL/min immediately after access creation and 946 mL/min (range of 645–1486 mL/min) at the patient’s last follow-up visit in the
of satisfaction with the procedure and the degree of pain associated with it (Table 2). These perceptions were reinforced in the focus group discussion as well as an appreciation of the avoidance a visible scar for aesthetic reasons related to body image an observation also made by other investigators.23

Author contributions

G.A.B. complied the initial draft and analyzed the data. T.L. collected and collated the data, and also edited the manuscript. W.C.J. analyzed the data and edited the manuscript.

Declaration of conflicting interests

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ORCID iDs

Gerald A Beathard https://orcid.org/0000-0002-0698-9329
William C Jennings https://orcid.org/0000-0003-3599-0609

References

1. Almasri J, Alsawas M, Mainou M, et al. Outcomes of vascular access for hemodialysis: a systematic review and meta-analysis. J Vasc Surg 2016; 64(1): 236–243.
2. Huber TS, Ozaki CK, Flynn TC, et al. Prospective validation of an algorithm to maximize native arteriovenous fistulae for chronic hemodialysis access. J Vasc Surg 2002; 36(3): 452–459.
3. Al-Jaishi AA, Oliver MJ, Thomas SM, et al. Patency rates of the arteriovenous fistula for hemodialysis: a systematic review and meta-analysis. Am J Kidney Dis 2014; 63(3): 464–478.
4. Scheltinga MR, vanHoeck F and Brujininkx CM. Time of onset in haemodialysis access-induced distal ischaemia (HAIDI) is related to the access type. Nephrol Dial Transplant 2009; 24(10): 3198–3204.
5. Basile C, Lomonte C, Vernaglione L, et al. The relationship between the flow of arteriovenous fistula and cardiac output in haemodialysis patients. Nephrol Dial Transplant 2008; 23(1): 282–287.
6. Sidawy AN, Spergel LM, Besarab A, et al. The Society for Vascular Surgery: clinical practice guidelines for the surgical placement and maintenance of arteriovenous hemodialysis access. J Vasc Surg 2008; 48(S Suppl.): 2S–25S.
7. Gracz KC, Ing TS, Soung LS, et al. Proximal forearm fistula for maintenance hemodialysis. Kidney Int 1977; 11(1): 71–75.
8. Jennings WC, Kindred MG and Broughan TA. Creating radiocephalic arteriovenous fistulas: technical and functional success. J Am Coll Surg 2009; 208(3): 419–425.
9. Jennings WC, Turman MA and Taubman KE. Arteriovenous fistulas for hemodialysis access in children and adolescents
using the proximal radial artery inflow site. J Pediatr Surg 2009; 44(7): 1377–1381.

10. Jennings WC. Creating arteriovenous fistulae in 132 consecutive patients: exploiting the proximal radial artery arteriovenous fistula: reliable, safe, and simple forearm and upper arm hemodialysis access. Arch Surg 2006; 141(1): 27–32; discussion 32.

11. Wu CC, Jiang H, Cheng J, et al. The outcome of the proximal radial artery arteriovenous fistula. J Vasc Surg 2015; 61(3): 802–808.

12. Malik J, Kudlicka J, Tesar V, et al. Cardiac safety in vascular access surgery and maintenance. Contrib Nephrol 2015; 184: 75–86.

13. Jennings WC, Landis L, Taubman KE, et al. Creating functional autogenous vascular access in older patients. J Vasc Surg 2011; 53: 713–719; discussion 719.

14. Jennings WC, Mallios A and Mushq N. Proximal radial arteriovenous fistula: reliable, safe, and simple forearm and upper arm hemodialysis access. Arch Surg 2006; 141(1): 27–32; discussion 32.

15. Hull JE, Elizondo-Riojas G, Bishop W, et al. Thermal resistance anastomosis device for the percutaneous creation of arteriovenous fistulae for hemodialysis. J Vasc Interv Radiol 2017; 28(3): 380–387.

16. Roberts JK, Sideman MJ and Jennings WC. The difficult hemodialysis access extremity: proximal radial arteriovenous fistulas and the role of angiography and valvulotomies. Am J Surg 2005; 190(6): 869–873.

17. Bonforte G, Rossi E, Auricchio S, et al. The middle-arm fistula as a valuable surgical approach in patients with end-stage renal disease. J Vasc Surg 2010; 52(6): 1551–1556.

18. Bhalodia R, Allon M, Hawxby AM, et al. Comparison of radiocephalic fistulas placed in the proximal forearm and in the wrist. Semin Dial 2011; 24(3): 355–357.

19. Capurro F, De Mauri A, Navino C, et al. The middle arm arteriovenous fistula is an additional option to expand autogenous hemodialysis access. J Vasc Access 2012; 13(2): 208–214.

20. Amaoutakis DJ, Deroo EP, McGlynn P, et al. Improved outcomes with proximal radial-cephalic arteriovenous fistulas compared with brachial-cephalic arteriovenous fistulas. J Vasc Surg 2017; 66(5): 1497–1503.

21. Hull JE, Jennings WC, Cooper RI, et al. The pivotal multicenter trial of ultrasound-guided percutaneous arteriovenous fistula creation for hemodialysis access. J Vasc Interv Radiol 2018; 29(2): 149.e145–158.e145.

22. Mallios A, Jennings WC, Boura B, et al. Early results of percutaneous arteriovenous fistula creation with the Ellipsys Vascular Access System. J Vasc Surg 2018; 68(4): 1150–1156.

23. Hebibi H, Achiche J, Franco G, et al. Clinical hemodialysis experience with percutaneous arteriovenous fistulae created using the Ellipsys(R) vascular access system. Hemodial Int 2019; 23(2): 167–172.

24. Jones RG and Morgan RA. A Review of the Current Status of Percutaneous Endovascular Arteriovenous Fistula Creation for Haemodialysis Access. Cardiovasc Interv Radiol 2019; 42(1): 1–9.

25. National Kidney Foundation. K/DOQI clinical practice guidelines for vascular access, update 2006. Am J Kidney Dis 2006; 48(Suppl. 1): S2–S90.
43. Lok CE, Sontrop JM, Tomlinson G, et al. Cumulative patency of contemporary fistulas versus grafts (2000-2010). Clin J Am Soc Nephrol 2013; 8(5): 810–818.
44. Asif A, Bakr MM, Levitt M, et al. Best vascular access in the elderly: time for innovation. Blood Purif 2019; 47(1–3): 236–239.
45. Mallios A, Jennings W and Beathard G. Early cannulation of percutaneously created arteriovenous hemodialysis fistulae. J Vasc Access. Epub ahead of print 19 December 2019. DOI: 10.1177/1129729819892796.
46. Xi W, MacNab J, Lok CE, et al. Who should be referred for a fistula? A survey of nephrologists. Nephrol Dial Transplant 2010; 25(8): 2644–2651.
47. Xi W, Harwood L, Diamant MJ, et al. Patient attitudes towards the arteriovenous fistula: a qualitative study on vascular access decision making. Nephrol Dial Transplant 2011; 26(10): 3302–3308.
48. Casey JR, Hanson CS, Winkelmayer WC, et al. Patients’ perspectives on hemodialysis vascular access: a systematic review of qualitative studies. Am J Kidney Dis 2014; 64(6): 937–953.
49. Kosa SD, Bhola C and Lok CE. Hemodialysis patients’ satisfaction and perspectives on complications associated with vascular access related interventions: are we listening? J Vasc Access 2016; 17(4): 313–319.