Revision of Aneurysmal Arteriovenous Access with Immediate Use Graft Is Safe and Avoids Prolonged Use of Tunneled Hemodialysis Catheters

Isaac N. Naazie, Claire Janssen, Sean Perez, Asma Mathlouthi, Luis Cajas-Monson, Mahmoud Malas, and Omar Al-Nouri, La Jolla, California

Background: Aneurysmal arteriovenous fistulas (AVF) can pose a difficult treatment dilemma for the vascular surgeons. Prolonged tunneled dialysis catheters (TDCs) in patients requiring long-term dialysis are associated with significantly increased mortality compared to AVF. We aimed to elucidate the outcomes of aneurysmal arteriovenous (AV) access revision with aneurysm resection and Artegraft® (LeMaitre, New Brunswick, NJ) Collage Vascular Graft placement to avoid prolonged use of TDCs.

Methods: We reviewed all patients with aneurysmal AV access in whom the access was revised with aneurysm resection and jump graft placement at a single institution from 2018 to 2021. Outcomes were time to cannulation, reintervention rates, time to reintervention, and patency (primary, primary assisted, and secondary). Patency rates were estimated with Kaplan–Meier Survival analysis.

Results: A total of 51 revised aneurysmal AV accesses in 51 patients were studied, of which 23.5% (n = 12) had perioperative TDC placement. Three patients were done for emergent bleeding. The cohort was 62.8% male (n = 32) with a median age of 58 years (interquartile range: 49–67). Most patients had brachiocephalic AVF (n = 37 [72.6%]). The median follow-up time was 280 days. The median time to cannulation was 2 days. Time to cannulation was significantly longer in patients with perioperative TDC as compared with those without TDC (24 days vs. 2 days, P < 0.001). Reintervention was required in 41.2% of patients (n = 21), at median time of 47 days. At 30, 90, 180, and 365 days, primary patency rates were 84.3%, 78.3%, 66.6%, and 54.9%; primary assisted patency rates were 94.1%, 88.1%, 79.4%, and 79.4%; and secondary patency rates were 100%, 97.8%, 91.6%, and 91.6%, respectively.

Conclusions: The revision of aneurysmal AV access (urgent or elective) with Artegraft as jump graft is safe, with acceptable short- and mid-term patency results. This allows dialysis patients to...
continue to have a functional access, decreasing the need for a tunneled catheter and reducing the associated risk of sepsis and increased mortality. This should be considered for all patients with aneurysmal, dysfunctional fistulas to maintain AV access and avoid TDC placement.

INTRODUCTION

Aneurysmal degeneration of arteriovenous (AV) accesses is a frequent complication and has been reported to occur in 5–43% of AV accesses.1–4 In fact, it has been reported as the most frequent complication of arteriovenous fistulas (AVF) in some series.5 Cannulation of an AV aneurysm should be avoided and their presence can thus limit cannulation sites.6 Aneurysmal degeneration of AVF can result in increased flow and high output can place strain on the heart. It can also lead to thrombosis, decreased flow for dialysis, prolonged bleeding after puncture, skin compromise, poor cosmesis, and infection. Although rare, aneurysm rupture and life-threatening hemorrhage can result.3

Long-term tunneled dialysis catheters (TDC) use is associated with significantly increased mortality compared to the use of AVF.5–9 Infection related mortality, cardiovascular related morality, and all-cause mortality have all been shown to increase when catheters are used for hemodialysis (HD), with mortality increasing 40–70%.9 Additionally, TDC placement can contribute to central venous stenosis and limit future access options. For these reasons, the Kidney Disease Outcomes Quality Initiative (KDOQI) guidelines favor AV access.5

In cases of symptomatic, large or rapidly expanding aneurysms, the KDOQI guidelines state that surgical management is reasonable based upon expert opinion.5 However, there is no consensus on the optimal surgical management of AV access aneurysms. Multiple techniques to salvage aneurysmal AV access have been described; however, many of these techniques require delay in cannulation and use of TDC.10–18 To prevent TDC placement and its inherent risks, the authors utilize a resection and immediate use graft to revise aneurysmal AVF.

Our objective was to determine the outcomes in HD patients in which aneurysmal AVF were revised with resection and use of the bovine carotid artery graft (Artegraft, Inc, North Brunswick, NJ) graft placement to avoid prolonged use of TDCs.

METHODS

Study Participants

We retrospectively reviewed and analyzed all patients who developed aneurysms after AV access creation and underwent revision at our institution. Patients were included from October 2018 to December 2021. The last day of follow-up for events was January 24, 2022. Three patients required emergent revision due to life threatening hemorrhage and aneurysm rupture, the remainder of the cohort was done electively. Individual patient informed consent and approval from our institution’s review board was waived since only deidentified data were used.

Revision Technique

Revision was done with surgical excision of the aneurysmal portion of the fistula and the overlying skin. Aneurysmal excision was chosen in patients who had a complication from aneurysmal AV access (i.e. bleeding, skin ulceration, skin thinning, and pending rupture). All patients underwent either preoperative or intraoperative fistulogram with treatment if necessary to relieve any outflow stenoses seen prior to revision. Perioperative TDC placement was only performed if the dialysis center had difficulty with cannulation. Interposition with the Artegraft as a jump graft was then done to salvage the AV access. The graft was tunneled lateral to the skin incision to allow for immediate cannulation postoperatively of the newly placed Artegraft (Fig. 1). Patients were not routinely anticoagulated after revision. They were placed back on their outpatient antiplatelet or anticoagulation regimen. A total of 11.8% of our cohort were on preoperative anticoagulation.

Outcomes

We evaluated both postoperative complications such as thrombosis, hematoma formation, stenosis, and infections. Outcomes were time to cannulation, reintervention rates, time to reintervention, and patency (primary, primary-assisted and secondary patency). By definition, patients were considered to have primary patency until it is lost when reintervention is required to maintain patency, the access is thrombosed or abandonment of the AV access, whichever occurs first. Primary-assisted patency was defined as any patency that ensues after reintervention except interventions for thrombosis. Patients were considered to have secondary patency after reintervention for thrombosis.
Table I. Baseline characteristics of study participants

| Variable                        | N (%) or median (IQR) |
|---------------------------------|-----------------------|
| Age                             | 58 (49–67)            |
| Gender                          |                       |
| Female                          | 19 (37.3)             |
| Male                            | 32 (62.8)             |
| Access type                     |                       |
| Radiocephalic AVF               | 6 (11.8)              |
| Brachiocephalic AVF             | 37 (72.6)             |
| Arteriovenous graft             | 8 (15.7)              |
| Body mass index                 | 26.7 (23.1–32.1)      |
| Obesity                         | 17 (33.3)             |
| Diabetes                        | 31 (60.8)             |
| Coronary artery disease         | 10 (19.6)             |
| Congestive heart failure        | 10 (19.6)             |
| Atrial fibrillation             | 7 (13.7)              |
| Hyperlipidemia                  | 23 (45.1)             |
| Chronic obstructive disease     | 1 (2.0)               |
| Pneumonia                       |                       |
| Anticoagulation                 | 6 (11.8)              |
| Tunneled dialysis catheter      | 12 (23.5)             |
| Preop TDC                       | 9 (17.7)              |
| Intraop TDC placement           | 3 (6.0)               |
| Time to cannulation, days       | 2 (1–3)               |
| Without TDC                     | 2 (1–3)               |
| With TDC                        | 24 (4–31)             |
| Follow-up time, days            | 280 (115–577)         |

Statistical Methods

All statistical analyses were performed with Stata/SE 16.1 (StataCorp LP, College Station, TX). The baseline characteristics of study participants and outcomes were analyzed and presented. Continuous variables were presented as a median with the corresponding interquartile range (IQR), while categorical variables were presented as counts and percentages. Patency rates were estimated with Kaplan–Meier survival analysis. For comparative analyses, statistical significance was accepted when P values of tests ≤0.05.

RESULTS

A total of 51 revised aneurysmal AV accesses in 51 patients were studied. Three patients were done for emergent bleeding. The cohort was 62.8% male (n = 32) with a median age of 58 years (IQR: 49–67). A total of 31 patients (60.8%) had diabetes. Most patients had brachiocephalic AVF (n = 37 [72.6%]). A total of 12 patients (23.5%) had perioperative TDCs, 9 placed preoperatively and 3 placed intraoperatively. The median follow-up time was 280 days. The median time to cannulation was 2 days. Time to cannulation was significantly longer in patients with perioperative TDC as compared with those without TDC (24 days vs. 2 days, P < 0.001). Additional details about the study participants are displayed in Table I.

The most common complications were thrombosis and hematoma formation. Thrombosis occurred in 15.7% (n = 8) of patients at a median time of 80 days whereas hematoma formation occurred in 7.8% (n = 4) of patients at a median time of 4 days, with 1 patient requiring reintervention during the index admission, Table II. Reintervention to maintain patency was required in 41.2% of patients (n = 21). The median time to reintervention was 47 days (IQR: 19–160 days). Table III provides overall functional patency rates. The primary patency was 84.3% at 30 days, 78.3% at 90 days, 66.6% at 180 days, and 54.9% at 1 year (Fig. 2A); the primary-assisted patency rates were 94.1% at 30 days, 88.1% at 90 days, 79.4% at 180 days, and 79.4% at 1 year (Fig. 2B) and the secondary patency rates were 100% at 30 days, 97.8% at 90 days, 91.6% at 180 and 91.6% at 1 year, respectively (Fig. 2C).

DISCUSSION

Our study demonstrates that placement of immediate use of arteriovenous grafts (AVG) for aneurysmal AV access is a safe option for revision of access that is at risk of rupture, as well as emergent salvage of access that has already ruptured. We demonstrate acceptable primary, primary-assisted, and secondary patency rates in our cohort of patients, as well as a high rate of technical success in cannulating the newly created AV access within 48 hr after creation. Previous studies19 have demonstrated early cannulation of Artegraft is safe either when used as a primary access or during revision, similar to our findings. Importantly, in the majority
of our cases, patients were able to avoid TDC placement and the intended risks that occur with prolonged TDC use. As we previously discussed, limiting the time that patients are dependent on TDCs is a necessity in the care of patients on HD due to their high risk of morbidity and mortality.

While previous studies have shown that AVG placement in the setting of patients undergoing HD results in fewer catheter days than if they were to have AVF placement, less work has evaluated the feasibility of revising aneurysmal AV fistulae/grafts already in place and its ability to decrease catheter use. Alternative options for management of aneurysmal fistulas include ligation and creation of a new AV access or other techniques to revise the aneurysmal AV accesses. Revisional techniques that have been studied include various techniques to reduce aneurysmal diameter including stapled plication, partial aneurysmectomy, and reinforced venous aneurysmorrhaphy. Most of the previously described techniques required TDC placement and a prolonged time until cannulation. Vo et al. performed aneurysm plication using a linear stapler to resect the redundant aneurysm down to a 6–8 mm diameter, with the staple line positioned laterally to avoid cannulation. They report no wound complications and no mortality in 30 days. These patients were not cannulated until 4 weeks postoperatively and thus required TDC use. Partial aneurysmectomy is one of the more promising of the alternative revision options, however, several technical variations have been described. Almehmi et al. studied partial aneurysmectomy in 36 patients, where they resected diseased skin and aneurysm wall followed by suture repair of the aneurysm wall and overlying skin using surrounding healthy tissue. Their patients did not require TDC placement, and they report primary patency of 56% and primary-assisted patency of 97% at 6 months. This technique has the advantage of avoiding graft placement and subsequent thrombotic complications. In fact, no reported complications were seen in their series. Despite their promising results they had a smaller sample size and did not have long-term follow-up. Woo et al. also describe a technique of partial aneurysmectomy performed in 19 patients where they excised excess length, reduced the luminal diameter, and reconstructed the fistula over a catheter guide. However, these patients were not cannulated immediately, and all underwent TDC placement with a median TDC removal at 8 weeks postoperation, no specific complication rate was reported, but 2 deaths occurred and 6 of their 19 patients required reintervention or ligation. One disadvantage of partial aneurysmectomy is there remains potential for recurrent aneurysmal degeneration. To address this shortcoming, techniques to reinforce the vein have been attempted. Berard et al. wrapped a polyester mesh around the vein to serve as an exoprosthesis in 33 patients. The report showed primary patency at 1 year of 93% but their patients were not cannulated for 30 days and all patients required TDC placement. The authors did not report a specific complication rate, but had hematoma formation prior to discharge in 2 patients, skin necrosis requiring explant in 1 patient and stenosis requiring intervention in 1 patient. There are many advantages of the technique utilized by the authors of this article. Namely, the ability to immediately cannulate for dialysis allows for avoidance of prolonged dialysis catheter use.

Additionally, resection with interposition graft placement using other conduits (reverse great saphenous vein (rGSV), polytetrafluoroethylene (PTFE)) has been studied. Pierce at al. performed interposition graft replacement for aneurysmal AVF revision, using PTFE in 3 patients and rGSV in 7 patients, and report a lower thrombosis rate in rGSV grafts at 14% compared to PTFE (33%) but are limited by a small sample size. In a randomized prospective study comparing PTFE to the bovine carotid artery as conduits for HD access, the bovine carotid artery demonstrated superior outcomes with lower thrombotic complications and a less frequent need for interventions to maintain patency. Arhuidese et al. also compared bovine carotid artery to PTFE in HD access in a retrospective review of 120 patients, and found no significant difference in primary or primary-assisted patency, although there was improved secondary patency with bovine carotid artery. They found secondary patency was 71% vs. 51% at 6 months, 67% vs. 48% at 12 months, and 67% vs. 38% at 24 months for the

| Patency type     | 30-day (%)  | 90-day (%)  | 180-day (%) |
|------------------|-------------|-------------|-------------|
| Primary, %       | 84.3 (71.1–91.8) | 78.3 (64.3–87.4) | 66.6 (49.9–78.8) |
| Primary assisted, % | 94.1 (82.9–98.1) | 88.1 (75.3–94.5) | 79.4 (63.4–89.0) |
| Secondary, %     | 100         | 97.8 (85.3–99.7) | 91.6 (75.7–97.3) |
bovine carotid artery versus PTFE. However, there are also studies suggesting equivalence between the two conduits, including a systemic review by Kostakis et al. that found no significant difference in complications or patency rates between the two conduit choices. Notably, the above studies were evaluating new access creation but their results are likely applicable to HD access revision as well and contributed to our choice to use the Artegraft as the conduit for these patients.

Another advantage of aneurysmal resection with jump graft interposition is in preserving future access sites. By revising and not immediately creating new HD access we are able to increase the longevity, thereby maintaining future access site availability when primary and secondary patency of these grafts

Fig. 1. Preoperative, intraoperative, and postoperative images of revision technique.

Fig. 2. Patency rates. (A). Primary patency. (B). Primary assisted patency. (C). Secondary patency.
are lost. Refraining from placing additional access in less desirable locations such as the dominant upper extremity or lower extremities may have substantial quality of life benefits for our patients. Pike et al., found that lower extremity accesses have poor primary patency rates in a retrospective review of outcomes from the vascular quality initiative.24 Others have demonstrated that avoiding central catheters and utilizing fistulas for HD increases quality of life for patients.25 Given our desire to limit the use of TDC in active dialysis patients, most aneurysmal AV access are treated with aneurysm resection with prosthetic jump graft placement. Even in instances of graft infection with rupture, we feel it prudent to perform this technique. Plication and other techniques aimed at avoiding prosthetic use, is considered to salvage an aneurysmal access in patients who are not actively using the access for hemodialysis needs. Based on our promising results we recommend consideration of revision by aneurysm resection and Artegraft interposition graft for all patients with aneurysmal, dysfunctional fistulas to maintain AV access and avoid TDC placement.

This study is not without limitations, one of which is our sample size and demographics. This study was performed at a single institution over the course of 3 years. Although our sample size is small, it is the largest sample size reported to date for revision of aneurysmal AV dialysis access. It is worth noting that a large portion of the complications resulting in secondary interventions were encountered early on within this study. As surgeon experience grew with small refinements in tunneling technique, complication rates dropped significantly in the later portion of the study. This suggests that our results for primary patency may improve with increasing surgeon experience in performing the procedure.

The purpose of this study was to evaluate the practice of aneurysm resection with interposition graft placement as a viable option for revision of aneurysmal HD access when compared to other previously described methods. Though we have demonstrated the adequacy of this method with benefits to the patient and a possible reduction in morbidity, as well as mortality from TDCs, going forward, it would be pertinent to study and compare these methods of interventions directly. As with any study assessing surgical procedures, outcomes can be operator-dependent. Future evaluation should include larger multi-institutional studies and evaluation of long-term functional patency.

REFERENCES

1. Al-Thani H, El-Menyar A, Al-Thani N, et al. Characteristics, management, and outcomes of surgically treated arteriovenous fistula aneurysm in patients on regular hemodialysis. Ann Vasc Surg 2017;41:46–55.
2. Bachleda P, Utkal P, Zadrazil J, et al. [Aneurysm as a complication of arteriovenous anastomoses for hemodialysis.] Rozhl Chir 1998;77:541–4.
3. Valenti D, Mistry H, Stephenson M. A novel classification system for autogenous arteriovenous fistula aneurysms in renal access patients. Vasc Endovascular Surg 2014;48:491–6.
4. Fokou M, Teyang A, Ashantantang G, et al. Complications of arteriovenous fistula for hemodialysis: an 8-year study. Ann Vasc Surg 2012;26:680–4.
5. Lok CE, Huber TS, Lee T, et al. KDOQI clinical practice guideline for vascular access: 2019 update. Am J Kidney Dis 2020;75:S1–164.
6. Locham S, Naazie I, Canner J, et al. Incidence and risk factors of sepsis in hemodialysis patients in the United States. J Vasc Surg 2021;73:1016–1021.e3.
7. Dhingra RK, Young JW, Hulbert-Shearon TE, et al. Type of vascular access and mortality in U.S. hemodialysis patients. Kidney Int 2001;60:1443–51.
8. Bream PR. Update on insertion and complications of central venous catheters for hemodialysis. Semin Inter Med 2016;33:31–8.
9. Wases H. Catheter-related mortality among ESRD patients. Semin Dial 2008;21:547–9.
10. Woo K, Cook PR, Garg J, et al. Midterm results of a novel technique to salvage autogenous dialysis access in aneurysmal arteriovenous fistulas. J Vasc Surg 2010;51:921–5. 925.e1.
11. Almeimi A, Wang S. Partial aneurysmectomy is effective in managing aneurysm-associated complications of arteriovenous fistulas for hemodialysis: case series and literature review. Semin Dial 2012;25:357–64.
12. Vo T, Tumbaga G, Aka P, et al. Staple aneurysmorrhaphy to salvage autogenous arteriovenous fistulas with aneurysm-related complications. J Vasc Surg 2015;61:457–62.
13. Lo HY, Tan SG. Arteriovenous fistula aneurysm — plicate, not ligate. Ann Acad Med Singap 2007;36:851–3.
14. Rokosny S, Baláž P, Wohlfahrt P, et al. Reinforced aneurysmorrhaphy for true aneurysmal haemodialysis vascular access. Eur J Vasc Endovasc Surg 2014;47:444–50.
15. Georgiadis GS, Lazarides MK, Panagoutsos SA, et al. Surgical revision of complicated false and true vascular access-related aneurysms. J Vasc Surg 2008;47:1284–91.
16. Hosny A. Partial aneurysmectomy for salvage of autogenous arteriovenous fistula with complicated venous aneurysms. J Vasc Surg 2014;59:1073–7.
17. DuBose JJ, Fortuna GR, Charlton-Ouw KM, et al. Utility of a tubularized extracellular matrix as an alternative conduit for arteriovenous fistula aneurysm repair. J Vasc Surg 2016;63:446–52.
18. Pierce GE, Thomas JH, Fenton JR. Novel repair of venous aneurysms secondary to arteriovenous dialysis fistulae. Vasc Endovascular Surg 2007;41:55–60.
19. Abdoli S, Mahajan A, Han SM, et al. Early cannulation of bovine carotid artery grafts (Artegraft) after primary vascular access and fistula revision procedures. J Vasc Surg 2018;68:1865–71.
20. Berard X, Brizzi V, Mayeux S, et al. Salvage treatment for venous aneurysm complicating vascular access arteriovenous fistulae: use of an endoprosthesis to reinforce the vein after aneurysmorrhaphy. Eur J Vasc Endovasc Surg 2010;40:100–6.
21. Kennealey PT, Elias N, Hertl M, et al. A prospective, randomized comparison of bovine carotid artery and expanded polytetrafluoroethylene for permanent hemodialysis vascular access. J Vasc Surg 2011;53:1640–8.

22. Arhuidese I, Reilsnyder T, Islam T, et al. Bovine carotid artery biologic graft outperforms expanded polytetrafluoroethylene for hemodialysis access. J Vasc Surg 2017;65:775–82.

23. Kostakis ID, Loukopoulos I. Comparison between bovine carotid artery graft and polytetrafluoroethylene graft for haemodialysis vascular access: a systematic review and meta-analysis. J Vasc Access 2021;22:26–33.

24. Pike SL, Farber A, Arinze N, et al. Patients with lower extremity dialysis access have poor primary patency and survival. J Vasc Surg 2019;70:1913–8.

25. Wasse H, Kuttner N, Zhang R, et al. Association of initial hemodialysis vascular access with patient-reported health status and quality of life. Clin J Am Soc Nephrol 2007;2: 708–14.