Mini Review

Hemodialysis vascular access options after failed Brescia-Cimino arteriovenous fistula

Aneesh Srivastava, Sandeep Sharma

Department of Urology and Renal Transplantation, Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow, Uttar Pradesh, India

ABSTRACT

The survival of patients on long-term hemodialysis has improved. End-stage renal disease patients now need maintenance of their vascular access for much longer periods. Arteriovenous fistulae formed at the wrist are the first choice for this purpose, but, in many patients, these fistulae fail over time or are not feasible because of thrombosed veins. We searched the Pubmed database to evaluate the various options of vascular access in this group of patients based on the published literature. It is quite evident that, whenever possible, autogenous fistulae should be preferred over prosthetic grafts. Use of upper arm cephalic and basilic veins with transpositions wherever required can enhance autogenous fistula options to a large extent. Upper arm grafts should be used when no autogenous fistula is possible. Lower limb and body wall fistula sites are to be considered at the end, when all options in both upper limbs are exhausted.

Key words: Arteriovenous fistula, autogenous AVF, graft AVF, vascular access.

INTRODUCTION

Autogenous arteriovenous fistulas (AVF) are the preferred mode of vascular access for maintenance hemodialysis (HD) in patients with end-stage renal disease (ESRD) because of their good long-term patency and low complication rate.[1] Brescia-Cimino radiocephalic AVF is still the procedure of choice of all forms of autogenous AVF. As the life expectancy of patients on long-term HD has improved with better healthcare facilities, most of them now stay on maintenance HD for much longer periods of time. Their vascular access also needs maintenance and management of various related complications. There is a large group of patients in whom Brescia-Cimino AVF has either failed in both upper limbs or is not feasible because of unsuitable veins. The best possible approach in the management of these patients to get a good long-term vascular access has been a matter of debate and discussion over the years.

We searched the PubMed database from January 2000 to October 2010 regarding various aspects of vascular access for HD after failed distal AVF. The aim was to review the literature on the subject that is of prime importance in the care of patients with ESRD. Our main focus was on autogenous fistulae and grafts either in the upper or in the lower limbs.

For correspondence: Prof. Aneesh Srivastava, Department of Urology and Renal Transplantation, SGPGI, Raebareli Road, Lucknow, Uttar Pradesh, India.
E-mail: anees892009@yahoo.in

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AUTOGENOUS FISTULA

Proximal forearm

Cephalic vein

After failure or nonfeasibility of distal radiocephalic AVF, consideration should be given to more proximal sites in the forearm. Direct radiocephalic fistula at a more proximal site in the forearm can be constructed. The forearm cephalic vein can also be transposed straight if it is lying at a distance from the radial artery or a loop transposition can be performed to get an arterial inflow from the proximal radial/brachial artery.[2] Gefen *et al.* evaluated forearm loop fistulae in diabetic patients.[3] On the basis of the good patency rates achieved, they recommended that these fistulae are a valuable option specially in diabetic patients who tend to have suboptimal arteries in the distal forearm because of atherosclerosis. Heavily calcified or atherosclerosed arteries are responsible for the high rate of nonmaturation of distal radiocephalic fistulae in diabetic patients. Asif *et al.*

highlighted that the internal diameter of the feeding artery <2 mm or presence of arterial calcification is associated with a high primary failure rate.[4]

Basilic vein

If the cephalic vein is not available, the forearm basilic vein is the next option. But, owing to its posteriomedial position, transposition is almost always required. Recently, Son *et al.* in a retrospective study compared forearm basilic vein transposition to radiocephalic AVF and forearm graft AVF.[5] The primary patency rates for radiocephalic AVF, basilic vein transposition and graft were 67.6%, 41.5% and 35% at 12 months and 53.9%, 30.2% and 10.3% at 24 months, respectively. The secondary patency rates were 89.2%, 79.1% and 78.3% at 12 months and 83.8%, 74.4% and 64.9% at 24 months, respectively. Clearly, fistulae created by basilic vein transposition have acceptable patency rates. Moreover, thromboses and infectious complications are less than grafts. Weyde *et al.* analyzed the formation of native forearm basilic vein fistulae using either radial or ulnar arteries in 27 patients over a period of about 10 years.[6] AVF creation was successful in 22 patients (81.5%). The primary patency rate was 70.4% after 1 year, 61.6% after 2 years and 48.4% after 3 years. They concluded that basilic vein AVF was a valuable option where radiocephalic fistula has failed. The authors also felt that the forearm transpositions for AVF formation were underutilized.

Antecubital vein

Antecubital vein is another option for formation of autogenous AVF in the forearm. The median antecubital vein may be used directly or its perforator branch may serve that purpose, as described by Gracz.[7] In a study comparing perforating antecubital vein AVF with Brescia-Cimino AVF and graft AVF, Sparks *et al.* reported that the primary patency rate of the perforating vein fistula was significantly better than the Brescia-Cimino fistula ($P = 0.0015$) or the synthetic graft fistula ($P \leq 0.0001$).[8] They concluded that the perforating vein fistula has an excellent patency rate and appears to be a viable option for AV access after a failure of Brescia-Cimino fistula or when it is not technically feasible. Weyde *et al.* reported primary patency rates of 47% after 1 year, 43% after 2 years and 39% after 3 years in 77 patients of Gracz AVF.[9] The cumulative patency rates were 67% after 1 year, 56% after 2 years and 53% after 3 years. They also concluded that proximal radial artery-perforating vein fistulas have an acceptable survival rate and do not produce circulatory complications. The advantage of this type of an AVF is that it provides multiple outflows for cannulation as both cephalic and basilic veins get arterialized in the arm. The main veins in the arm remain preserved for future AVF construction.

Upper arm

Cephalic vein

Once the forearm veins are exhausted, the focus shifts to the upper arm. As in the forearm, the cephalic vein is preferred over the basilic vein for AVF because of its lateral position, which makes cannulation easy. In addition, the cephalic vein is relatively superficial and transposition is seldom required. Arterial inflow may come from either brachial or proximal radial artery, with the latter having the advantage of less chance of limb ischemia. Elcheroth *et al.* reported 1- and 4-year cumulative patency rates for upper arm brachiocephalic AVF to be 74.1 and 61.3%, respectively.[10]

Basilic vein

If the cephalic vein is not available in the upper arm, the basilic vein is selected for fistula creation. Only a small part of the basilic vein above the antecubital crease is superficial, while the rest of it is running deep to the fascia. This position protects the basilic vein from frequent venipunctures and, hence, it is usually patent and available for AVF formation. At the same time, the sub-fascial position of this vein makes its transposition to a more superficial and anterior position mandatory while formation of AVF to facilitate cannulation during HD access. Some authors have tried simple elevation of basilic vein in its anatomical position instead of transposition. Humphries *et al.* reported their series of 67 patients who received elevated brachiobasalic AVF over a 10-year period. Actuarial fistula patency was 84% at 1 year, 73% at 3 and 5 years and 52% at 10 years.[11] In another study, Hossny *et al.* compared 30 patients of basilic vein transposition with 40 patients in whom only elevation of the vein was performed.[12] They found that the elevation procedure was associated with a higher complication rate, especially hematoma formation. In case of elevation, it is better to raise a flap of the skin and position the basilic vein somewhat away from the incision so that surgical scar does not hinder palpation and cannulation of the vein later on.[13]

The brachiobasilic AVF can be created in a single stage or in a two-staged manner. In the two-stage method, the first stage involves anastomoses of the basilic vein to brachial artery in antecubutal fossa without mobilizing its proximal part. In the second stage, after 4–8 weeks, the arterialized vein is mobilized up to the axilla and transposed to the desired position. The idea is to avoid extensive dissection of the thin-walled vein in the first stage to prevent injury and decrease the chance of thrombosis. Francis *et al.* presented their experience with two-stage brachiobasilic AVF in 91 patients.[14] Primary and secondary patency rates were 87 and 89%, respectively, at 1 year and 78 and 84%, respectively, at 2 years. El Mallah reported better outcomes with the staged procedure in a prospective randomized trial comparing single-stage and two-stage brachiobasilic transposition AVF.[15] In the early postoperative period (4 weeks after operation), the patency rate was 12/20 (60%) in the single-stage group and 18/20 (90%) in the two-stage group, with a significant difference ($P< 0.05$). At the end of the follow-up period of 6–24 months, the overall patency was 10/20 (50%) and 16/20 (80%) in the two groups, respectively, with a significant difference between them. In a similar

study, Kakkos *et al.* reported that in the one-stage procedure (n = 76), the incidence of venous hypertension, wound hematomas and all complications (17%, 13% and 43%, respectively) was significantly higher than in the two-stage procedures (n = 98) (4%, $P = 0.004$; 3%, $P = 0.012$; 11%, $P < 0.001$, respectively).[16] The proposed benefits of the two-stage procedures are to some extent negated by the increased morbidity because of two surgical procedures, prolonged time interval before the fistula can be utilized for dialysis and extra cost, as the patient is hospitalized twice. Arroyo *et al.*, in their study, proposed a single-stage method for patients who had basilic vein 4 mm or more in diameter and the two-stage method for smaller-sized veins.[17] More such trials are needed at multiple centers before arriving at a final conclusion.

Conventionally, transposition of basilic vein has been a major surgical procedure requiring general anesthesia/nerve block and a long incision from the antecubital fossa to the axilla. Many workers have tried to make the procedure less morbid. One option is to make two or three small skip incisions instead of a long incision to dissect the basilic vein from its bed.[18] Another recently described technique uses an innovative vein inverter to help vein dissection.[19] Only small key hole incisions are made where any tributary of the vein is encountered that needs ligation and division. Similarly, dissection of the vein using an endoscopic technique has also been described but, somehow, it has not become popular.[20]

Brachial vein

Bazan *et al.* reported the use of the brachial vein for creation of AVF in 2004 as a new technique for patients with no usable superficial veins in the upper limb.[21] Dorobantu *et al.* reported their mid-term results in 49 patients in whom brachiobrachial AVF was constructed in two stages.[22] One month after surgery, 40 (81.6%) of these patients had a functional fistula, but in only 39 (79.6%) cases was the fistula suitable for HD following transposition to the subcutaneous tissue. Seventeen patients developed temporary edema of the forearm during the first month, in three cases the edema extended to the entire arm, but no other complications were associated with the procedure. Brachial vein is situated quite deep in the upper arm. Moreover, because of its limited available length, we suggest that formation of brachiobrachial AVF and its transposition should be undertaken only by surgeons with a good amount of experience in vascular access surgery. This technique is relatively new and more experience is required before its wider use could be recommended.

Lower limb AVF

In general, lower limb AVF is created only when it becomes absolutely necessary because of exhaustion of all upper limb options. This is because more complex surgical procedures are required in the lower limb for AVF creation. In addition, ischemic and infective complications requiring intervention are also more common in the lower limb. Saphenous or superficial femoral veins are commonly used for autogenous AVF construction in the lower limb, and arterial inflow is usually provided by either common femoral or superficial femoral arteries. Transposition is always required. Although use of posterior and anterior tibial arteries is also mentioned for creation of AVF at the ankle, the published data about patency and complication rates is scant.

Saphenous vein

The saphenous vein is transposed either straight or in a loop fashion to make AVF. There are conflicting results in the literature about the outcome of sapheno-femoral-transposed fistulae. Lynggaard reported very poor patency rates and unacceptably high complications in their series.[23] Pierre-Paul *et al.* published their results of sapheno-femoral loop AVF.[24] The mean primary patency was 7 months, primary-assisted patency was 15 months and secondary patency was 16 months. The fistula was functional for hemodialysis in 71.4%. All patients developed stenoses within the saphenous vein loop, with a mean of 3.0 balloon angioplasties per fistula. Three secondary surgical procedures were performed (two pseudoaneurysm repairs, one vein patch angioplasty). It appears from the available data that straight transposition of saphenous vein has better outcomes compared with loop configuration. Overall, the saphenous vein does not seem to be a very reliable venous conduit for AVF creation.

Superficial femoral vein

Just like the saphenous vein, the superficial femoral vein can also be transposed either straight or in a loop fashion to create AVF. Gradman *et al.* reported their initial experience with femoral vein AVF formation.[25] In their series, cumulative secondary fistula patency at 6 and 12 months was impressive in 91% and 86%, respectively. They had a high incidence of ischemic complications. One of their patients eventually had an above-knee amputation after experiencing an acute compartment syndrome. Eight patients required a second operation to alleviate a symptomatic steal syndrome. In conclusion, although patency rates were quite good, a high incidence of limb ischemia was the major impediment. Later, the same authors published their further experience with 55 cases of transposed femoral vein.[26] They used specific intraoperative measures to reduce the postoperative incidence of steal syndrome, such as tapering the femoral vein to 4.5–5 mm at the anastomosis and banding of the vein or closed fasciotomies to prevent compartment syndrome where indicated. They reported a significant reduction in ischemic complications requiring intervention with refinement of the technique.

To the best of our knowledge, there are no studies comparing saphenous and superficial femoral veins directly. Although the reported patency rates are higher for superficial femoral

vein, it has a high incidence of limb ischemia. More comparative studies are required in this field.

Grafts

The extent of use of prosthetic material for creation of AVF has varied significantly from one part of the world to the other. Whereas most parts of Europe have used grafts only to a limited extent, in the United States, there has been a fairly high usage of grafts in AVF construction.[27] The basic technique for use of grafts in creation of AVF involves two incisions, one for exposure of the feeding artery and the other for proposed venous outflow. The graft is then tunneled subcutaneously from one incision to the other and both ends are anastomosed end-to-side to the planned vessels. Prosthetic grafts have inferior primary and secondary patency rates and higher incidence of some complications such as infections and thrombosis compared with autogenous fistulae.[28-30] As a result, the last decade has seen a gradual and intentional shift toward increasing the use of autogenous AVF.[31,32]

Upper limb

Prosthetic grafts can be used in the upper limb for construction of AVF in three basic configurations.[2] The forearm grafts are used either in straight or loop configurations. In the straight variety, the distal radial artery provides inflow and venous outflow is through the antecubital vein. Loop graft is performed between brachial artery and antecubital vein. The upper arm grafts are placed between the brachial artery in antecubital fossa and the axillary or brachial vein in axilla. Keuter *et al.* compared brachiobasilic autogenous AVF with prosthetic forearm loop in a prospective randomized trial.[33] Primary and assisted-primary 1-year patency rates were significantly higher in the autogenous brachiobasilic group: 46% ± 7.4% vs. 22% ± 6.1% ($P = 0.005$) and 87% ± 5.0% vs. 71% ± 6.7% ($P = .045$). The rate of complications was 1.6 per patient-year in the brachiobasilic group vs. 2.7 per patient-year in the Polytetrafluoroethylene (PTFE) group. Other investigators have also confirmed the superiority of upper arm autogenous fistulae over forearm grafts.[29,30] Thus, in the presence of healthy upper arm veins, which is a prerequisite for placement of forearm grafts, placing upper arm autogenous fistulae should be preferred over forearm loop grafts. Many studies have compared upper arm autogenous fistulas with upper arm grafts.[34] Lazarides *et al.* conducted a meta-analysis comparing brachiobasilic AVFs with upper arm grafts.[35] They recommended use of brachiobasilic autogenous AVF prior to grafts based on their superior outcomes and lower complication rates.

Use of saphenous vein translocation to the upper limb (autograft) for creation of AVF is theoretically an attractive option. Results of saphenous vein translocation to forearm as a loop graft have not been consistent.[36,37] We could not identify any studies reporting the results of saphenous vein translocation to the upper arm as a graft between brachial artery and axillary vein. Being an autogenous graft, its results are expected to be better than prosthetic grafts, but, in the absence of any published evidence, it is difficult to make a recommendation.

Lower limb

The femoral artery to femoral vein loop graft is the most common form of prosthetic AVF in the lower limb. Another option is to use graft for formation of mid-thigh AVF where it has been used as a composite conduit along with superficial femoral or saphenous vein. Antoniou *et al.* compared the results of lower limb autogenous and graft AVFs in a systematic review of the literature.[38] They concluded that autogenous AVFs in the lower limb have better patency rates compared with grafts and are less likely to have infective complications. However, grafts had fewer incidences of ischemic complications in their study.

Body wall

These innovative sites are mentioned as the last resort of vascular access. Use of prosthetic material is generally required. Most of the body wall configurations use axillary artery as a source of inflow. Outflow can be obtained from contralateral axillary vein, ipsilateral axillary vein (axillary–axillary chest loop), internal jugular vein or femoral vein.[2,39]

It is observed that all the major forms of AVFs have a wide range of reported patency and attrition rates. This is because of variable definitions and reporting criteria followed in different studies, which makes them largely incomparable. In this scenario, it is extremely difficult to come forward with specific numbers to depict the overall patency rates for different forms of AVFs as would be desired from such a review.

Complications

Just like any other surgical procedure, creation of AVF has its own set of complications. Although detailed discussion on various aspects of these complications is beyond the scope of this article, giving a brief outline of some of the common complications will be most appropriate. Failure to become functional, thrombosis, bleeding, infections, pseudoaneurysm formation, venous hypertension, distal limb ischemia and neuropathies are some of the common surgical complications encountered by those involved in creation and maintenance of AVFs.

Nonfunctional AVF results from an access that may be too deep for cannulation or one that fails to mature either because of poor arterial inflow or venous outflow obstruction.[2] Careful clinical assessments followed by suitable investigations can, in many cases, pinpoint the diagnosis and guide the intervention to salvage the access. Once AVF has become functional, thrombosis is a common complication. Early thrombosis can occur from arterial,

venous or technical factors as well as from systemic factors such as hypotension and hypercoagulable states. If it is felt that the underlying cause can be corrected, thrombectomy is worthwhile, otherwise a new access should be planned. Late thrombosis is more common in prosthetic grafts. Stenosis at venous anastomosis due to intimal hyperplasia is the most common cause. Intervention can restore flow in some cases of late thrombosis, but, usually, the problem recurs. eventually leading to loss of the access. AVF-related infections are also more common in case of prosthetic grafts. Infections in autogenous fistulae respond to antibiotics most of the times unlike grafts where partial or complete excision of the prosthetic material is required.

Bleeding can complicate many AVF creation procedure as these patients tend to have platelet dysfunction secondary to uremia. Meticulous surgical technique and ensuring adequacy of HD before the procedure can prevent this complication in many of these patients. Pseudoaneurysm formation is another complication that generally requires urgent attention. Surgical intervention is required to prevent rupture if the anastomotic site is involved, which usually occurs secondary to infection. Small pseudoaneurysms at the sites of repeated punctures generally subside over time if the overlying skin is intact.[40]

Venous hypertension results from excessive retrograde flow from the venous component of the AVF. It is more common with the side-to-side configuration of AVF. In end-to-side fistulae, it may be the result of venous outflow obstruction at the regional level or central venous stenosis. The end result is venous insufficiency in the limb presenting as edema, pigmentation, thickened skin and, in severe cases, ulceration. Depending upon the cause of venous hypertension, treatment is done by ligation of the venous tributary responsible for retrograde flow or by angioplasty to correct stenosis of the outflow venous channels. Peripheral neuropathy related to functional AVFs is either a result of chronic tissue edema resulting in nerve entrapment, e.g. carpal tunnel syndrome, or is caused by distal limb ischemia.[40]

CONCLUSIONS

Based on these observations, we can make some proposals to help decision making for optimal patient outcome [Figure 1]. Basic principles of using distal sites first and preferring autogenous fistulae over grafts are the mainstay of decision making. Among autogenous fistulae, direct fistulae, transpositions and translocations should be considered in that order with an aim of performing simpler and less-morbid procedures first. Lower limb and body wall sites should be considered after all upper limb options are exhausted. Use of nondominant hand first holds true only when access opportunities are equal on both sides, otherwise hand with more suitable veins gets preference.[2] Thus, after distal

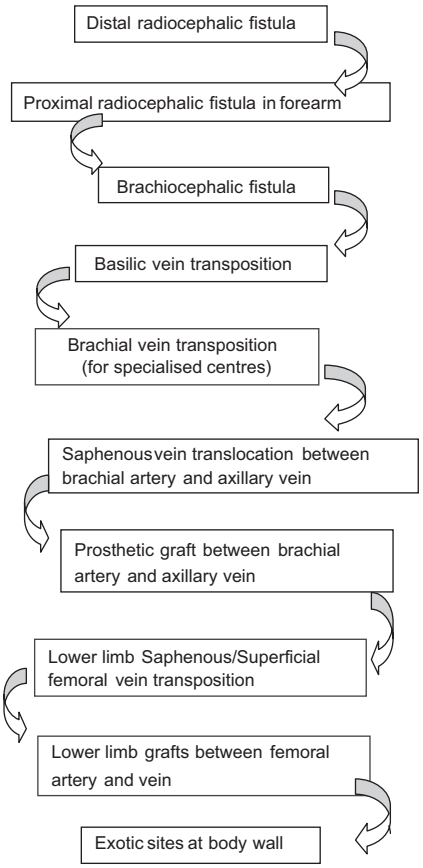

Figure 1: Algorithm for construction of vascular access in CRF patients

radiocaephalic fistulae have failed in both arms, the next option should be direct radiocephalic fistula at a more proximal site in the forearm. If that is not possible, cephalic or basilic vein transposition should be considered. In diabetic patients, it may be prudent to consider proximal forearm options as primary vascular access without trying Brescia-Cimino fistula when radial artery at wrist is calcified or seems inadequate on Doppler study. In the upper arm, the brachiocephalic fistula gets preference over basilic vein transposition. When even basilic vein is not available, brachial vein may be tried but only at specialized centers. Once all options of upper limb autogenous fistulae are ruled out, prosthetic graft should be placed between brachial artery and axillary vein. We have not considered forearm grafts here because we feel that there is a fair amount of evidence suggesting that upper arm autogenous fistulae have better outcomes compared with forearm grafts. In the lower limb, either saphenous or superficial femoral veins can be used depending on the surgeon's preference. Use of lower limb grafts should be the last option before trying other exotic sites on the body wall.

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