Autogenous Arteriovenous Fistula: A Review

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ABSTRACT
Since the introduction of the Brescia-Cimino surgical technique as access for chronic hemodialysis patient, a lot of modification of this technique has taken place. These were aimed at improving the utilization of autogenousarteriovenous fistula (AVF) by the patients with end stage renal disease (ESRD). The initial high primary failure rates lead to identification of some demographic, co-morbidity, anatomic and surgical factors that when corrected,contributed to the improve fistula patency and maturation rate. This review stressed the need for patient education, pre-operative, intra-operative and post-operative modifiable factors that would increase the creation of autogenousarteriovenous fistula. It also stressed the value of creating brachio-cephalic AVF as the primary fistula for diabetic based on the peculiar nature of their vessels and their short life expectancy. The underlying pathological basis and management of common complications that could follow the various types of autogenous AVF is discussed. Autogenous AVF despite it constraint remains the cheapest and best vascular access for ESRD patient who require chronic hemodialysis.

INTRODUCTION

Worldwide there is an annual increase in the patients with end stage renal disease (ESRD) [1]. These patients are living longer and besttreated with one form of renal replacement or the other. The immediate option of management is hemodialysis that is best accomplished with a vascular access. There are three types of permanent vascular access namely; arteriovenous fistula (AVF),arteriovenous grafts (AVG) and cuffed tunneled central venous catheters (CVC). The CVC should be discouraged because it predisposes to infection and dysfunction [2].

In 1960, Quinton et al designed an external shunt for the maintenance hemodialysis but this was complicated by clotting and infection [3]. Brescia-Cimino et al. (1966) described the radiocephalic fistula, an internal shunt that gained popularity and has undergone a lot of modifications [4]. The arteriovenous graft (AVG) fistula made of polytetrafluoroethylene (PTFE) was introduced in 1969 and it accounts for 80% of primary vascular accesses created in the United States. The AVG is less frequently used in other countries. It has been recognized that the outcomes of PTFE grafts are poorer compared to autogenous AVFs [5]. AVG has a short life span and is more prone to recurrent stenosis and thrombosis. AVG often requires multiple salvage procedures to maintain its patency [6].

The preferred vascular access is autogenous AVF [7]. The autogenous AVF is reliable, has fewer complications [2, 8, 9,], often less infected and decreases mortality [10]. However, it has a high primary failure rate up to 50% in some centers [7, 11]. The brachiocephalic AVF (BC-AVF) and

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brachiobasilic vein transposition are alternative procedures in patients with failed radiocephalicarteriovenous fistula (RC-AVF). These are the preferred vascular access in diabetics because of early maturation and less infection [12, 13, 14]. The BC-AVF has the advantage of higher blood flow compared to the RC-AVF, easy to cannulate and easily covered by clothes [15]. However, it is technically more difficult to create surgically, may result in arm swelling and has a higher incidence of steal phenomenon than RC-AVF [2].

This is a review of the factors that may affect the outcome of AVF creation and the management of some of these complications. This became necessary in Africa, where the management of ESRD is challenging and only a few patients are able to afford dialysis and kidney transplantation [16, 17].

Education and enlightenment

There is a need for thorough education and motivation of the patient on what arteriovenous fistulas are. The possible complications and their respective management must be emphasized.

Repeated puncture of the arm vein and the resultant scar (Figure 1) will interfere with the harmonious dilatation and vein remodeling. This ultimately cause turbulent flow within the vein and predispose to stenosis. Therefore, one should avoid the use veins of both arms. If a patient requires venipuncture, then the veins of the dorsum of the hand could be used and if there is any difficulty, then warm the hand [18]. In sub-Saharan Africa, majority of patients with ESRD tend to present late and cannot afford more than two to three sessions of dialysis [16]. These categories of patient really require education and motivation on their clinical condition.

Clinical assessment of the patient

The clinical history is often easily ascertained. These include oliguria or anuria, facial swelling, easy fatigability, dyspnoea at rest and on exertion, cough, and bilateral pedal oedema. The patients with urological cause of their renal impairment may present with lower urinary symptoms. The examination may confirm pallor, tachycardia, hypertension, abdominal distension (that may indicate ballotable kidneys, distended urinary bladder), pitting pedal oedema.

The patients with ESRD needshaematological, biochemical and imaging studies to establish the diagnosis. A complete blood count may confirm the presence of anaemia and thrombocythopaenia. Serum fasting blood sugar > 120mg/dl and 2 hour postprandial > 180mg/dl is suggestive of diabetes mellitus. The serum electrolytes would show hyperkalaemia, acidosis, azotaemia, hyperuricaemia, and hypercreatinaemia.

The chest radiograph may show evidence of pulmonary oedema, cardiomegaly or aortic unfolding.

Fig. 1: The blue arrows indicate the scars on the skin along the left cephalic vein from repeated forearm vein punctures.

The abdominal ultrasound may confirm the presence of polycystic kidney disease, bilateral renal scarring (suggestive of chronic pyelonephritis), bilateral hydronephrosis, dilated bladder and significant residual urine (that suggest bladder outlet obstruction). The voiding cystogram may show dilated posterior urethral (suggestive of posterior urethral valves).

Urethrocystoscopy may identify posterior urethral valves, abnormalities with the ureteric orifice such as stadium or gulf ball appearance suggestive of vesico-ureteral reflux.

Collateral vasculature assessment

This pre-operative evaluation aims at assessing the suitability of the forearm arm veins and radial artery. The modified (three digit) Allen's test is the clinical method of establishing the patency of the palmar arches. It provides a subjective assessment of the radial arterial inflow to the hand and defines the dominance of the radial or ulnar artery. The hand is elevated, the fist clenched, both radial and ulnar arteries are compressed with three digits and the hand becomes blanched. The ulnar arterial compression is then released, while maintaining the radial artery compression; the hand becomes flushed if the ulnar artery can adequately supply the palmar arches. Delayed hand flush more than 7 second suggest a negative test, therefore the radial artery should not be cannulated[19].

In the patient with small cephalic vein, the venous diameter could be assessed before and after application of a tourniquet. A post venous tourniquet cephalic vein diameter greater than 4mm is adequate. This technique has increased the number of patients who are eligible for forearm AVF without decreasing the adequacy rate of the fistula [20].

The duplex scanning or Doppler ultrasound can delineate the diameter of the forearm vein and radial artery [21,22].

Surgical technique

The kidney disease outcome and quality initiative (KDOQI) guidelines recommend that vascular access for hemodialysis should be considered when the following are present; serum creatinine concentration above 4mg/dl and glomerular filtration rate (GFR)≤ 25ml/minute. This access should be established at least 3 to 4 months before the scheduled beginning of dialysis. This is referred to as pre-emptive AVF [7]

Three types of anaesthesia can be considered in AVFs creation. They are local anaesthesia, brachial block and general anaesthesia[18]. At our centre, we routinely infiltrate the skin with 0.5% xylocaine with adrenaline and this is well tolerated by the patient. The problem with this method is local inflammatory oedema that may impair the flow through fistula anastomosis. Oedema can be minimized by careful tissue dissection and applying loose interrupted non-absorbable fine 3/0 nylon sutures. The brachial block has the advantage of allowing a smooth surgery in a well relaxed patient. However, it requires very experienced and dedicated anesthesiologist. We use this approach sparingly in our centre. General anesthesia is rarely used in our centre.

Brescia-Cimino side-to-side anastomosis was the first surgical technique fashioned as autogenous vascular access for hemodialysis [4]. Later on, the end-to-end technique became popular but currently, the most frequently used technique is the side- to-end anastomosis. In the side-to-side anastomosis (Figure 2), the side of the radial artery is anastomosed to the end of the distal branch of the cephalic vein. The advantage of this technique is that it is easy to create. The disadvantage is the risk of venous hypertension. This can be prevented by ligating the distal run-off vein, thus mimicking a functional side-to-end anastomosis.

Fig.2: Shows side-to-side left radiocephalicarteriovenous fistula. Double ended arrow is on the cephalic vein and the vertical arrow- up is on the radial artery

In the end-to- end anastomosis of radial artery to distal cephalic vein, the anastomosis is technically more difficult, particularly when there is significant discrepancy in the diameters of the radial artery and cephalic vein. The advantage of this technique is that, there is limited flow within the fistula and this prevents the hypercirculatory state that causes congestive cardiac failure seen in other techniques of autogenous AVF. However, in the event that venous thrombosis occurs, this may extend into the radial artery.

The side-to-end anastomosis (Figure 3) is the mostly commonly performed technique. This is indicated when the artery and vein are far apart and in bringing them together one must avoid an acute angle that may predispose to fistula failure. When there is fistula failure, it is easy to reverse and allows opportunity for more proximal anastomosis. If venous thrombosis develops, it does not extend into the radial artery. The side-to-side anastomosis is what we perform routinely at our centre.

The routine use of antibiotics is not recommended except in diabetics, patients with infected fistula or patients scheduled for arteriovenous graft surgery [18].

Fig. 3: Shows side-to-end left radiocephalicarteriovenous fistula. Vertical arrow indicates left cephalic vein and horizontal arrow is on the radial artery.

Monitoring of AVFs

A primary AVF is mature and suitable for use when the vein's diameter is sufficient to allow successful cannulation, usually not sooner than 1 month but preferably 3 to 4 months after construction [2]. Studies have confirmed that the RC-AVF matures in 4 to 6 weeks and the BC-AVF in 2 to 3 weeks [12, 23]. This is our experience in Ibadan.

The sonographically mature fistula is defined as a fistula with a diameter of at least 4 mm, an access flow of at least 500 mL/min, and a depth of no more than 5 mm from the skin surface[24]. And the clinically mature fistula is the fistula that could be used for dialysis for at least 1 month (reference) [25]. The post -operative ultrasound can be used to identify clinically immature fistulas with remediable causes and determine appropriate angioplasty or surgical intervention [26]. The chances of a fistula being adequate for dialysis is doubled when the venous diameter is $\geq$ 0.4 cm thanwhen it is < 0.4cm ($p<0.001$). Similarly, when the flow volume is e" 500ml/ min than when it is < 500ml/min ($p= 0.002$) [27].

The fistula hand-arm exercise e.g. squeezing a rubber ball with or without a lightly applied tourniquet does increase blood flow and is believed to speed maturation of a primary fistula [2]. Though the hand-arm exercise is physiologically sound, studies have not confirmed it [18].

Factors that may affect fistula outcome

Demographic, anatomic and clinical parameters have been found to contribute to the outcome of AVF. Primary AVF failure was significantly higher in ESRD patient older than 65years ($p<0.001$); history of cigarette smoking ($p<0.001$); diabetes mellitus ($p=0.007$); presence of coronary artery disease and peripheral vascular disease [28, 29, 30]. Afore mentioned result in a reduced flow within the radial artery that is due to either arteriosclerosis or arthrosclerosis. When the gender of ESRD patient was considered, the primary access failure was lower in males than in females [22, 31].

Anatomic problems: (a) Stenosis at or near the arteriovenous anastomosis impairs blood flow into the draining vein. (b) The presence of one or more accessory veins branching off of the main draining

vein near the arterial anastomosis. This leads to escape of the fistula blood flow out of the main draining vein. (c) The deep location of the draining vein within the subcutaneous tissues, this could prevent safe cannulation[24, 32].

The patient education on the symptoms of renal impairment, early hospital presentation is necessary. This would allow prompt evaluation, education on the preservation of the cephalic veins and appropriate timing of AVF placement. In addition coordinated public healthcare policy, proper practitioner training, and available interventions all could contribute to the success of a functioning fistula[33, 34].

The analysis of the Dialysis Outcomes and Practice Patterns Study noted that risk of primary fistula failure was 34% lower (relative risk = 0.66, p = 0.002) when placed by surgeons who created more than 25 compared to less than 25 fistulae during training [35]. Fassiadis N *et al*, in their study documented that the primary success rate of AVF placement by consultant and residents in the same surgical unit was 94.2% and 81% . And they confirmed that radiocephalic fistula should be placed by the most experienced member of the team [36]. Thus the surgical training is paramount to both fistula placement and survival.

The use of Doppler ultrasound or duplex scanning could delineate the diameters of the proposed vein and artery. The finding of vein diameter e" 2.5mm and radial artery e" 2mm would determine the proper choice of AVF type and location. Studies have demonstrated that thepreoperative vascular mapping improve AVF patency rates when compared with preceding experience in which vascular mapping was not employed [18, 21, 35, 37]. The impact of routine preoperative vascular mapping on the type and outcomes of vascular access placement was also evaluated in a prospective studyby O'Hare *et al*. The study showed that vascular mapping resulted in an increase in the proportion of fistulae placed from 34% to 64% ($p< 0.001$) and there was significant improvement in primary patency. The initial adequacy, in a subset of forearm fistulae, increased substantially from 34% to 54% ($p=0.06$) with the greatest improvement noted among women and diabetics[37]. In patients with diabetes, coronary artery disease and peripheral arterial disease, duplex scanning does improve the fistula outcome [38, 39]. The pre-operative, intra-operative and post- operative use of Doppler ultrasound and meticulous surgical technique lead to a cumulative patency rate of 100% at 12 months and 95.7% at 24 months for radiocephalic AVF in a study by Jennings WC *et al* [22].

The successful creation of arteriovenous fistula is multidisciplinary and involves the nephrologist, the surgeon, the ultrasonographer, and the interventional radiologist who should work together as 'the fistula team'. The autogenous AVF should be carried out by dedicated surgeons [40].

Complications of AVF

Primary Failure

This is the inability to cannulate a fistula successfully within 6 months of it creation with two needles over a period of at least 1 month [25].

In Nigeria, where autogenous AVF creation is being encouraged, the primary failure rate was as low as 9% in Maiduguri [9], and 18.4% in Jos [41]. In Europe primary failure rate varied between 10% and 40% [42, 43]. The reasons for this observed failure rate includes small caliber of vessels, technical factors, presence of old age, obesity, thrombosis, arteriosclerosis, arthrosclerosis, and diabetes mellitus

Steal phenomenon/ vascular steal syndrome

There are two varieties of vascular steal: high-flow steal (when fistulae with very low resistance "suck-off" blood flow from the palmar arc and the opposite ulnar artery, thus creating critical ischemia of the fingers) and low flow steal (result of stenosed peripheral arteries so that even normal blood flow in the fistula will create critical ischemia in distal vascular beds)[18]. The treatment of high flow steal is to reduce fistula flow by limiting the anastomotic diameter to 75% or less of the proximal arterial diameter which translates into arteriotomy length of approximately 5mm[44, 45]. Treatment of low flow steal includes that proposed by Schanzer[46] and renamed DRIL (distal revascularization–interval ligation). The artery distal to the anastomosisis ligated and the peripheral arteryis fed via an interposed segment of saphenous vein or PTFE graftto raise the perfusion pressure[47].

Aneurysm

This usually results fromthe destructionof the vessel wall and the replacement by biophysically inferior collagenous tissue. Aneurysm formation is usuallya result of the area puncture technique. Such aneurysms area composite of true and false aneurysms, intact

parts of thewall alternating with scar tissue. Thinning of the wall of thevein causes progressive enlargement of the aneurysm, becausewall stress increases progressively with increasing lumen diameteraccording to the Laplace law[18].Doppler ultrasonography would identify thrombi, the degree of outflow stenosis and the pre-stenotic rise of outflow pressure. The major complications are rupture and infection [14]. The surgicalcorrection includes partial or complete resection of the aneurysm, correction of accompanying stenosis, and reconstructionof an adequate lumen.

Pseudoaneurysm is a recognized complication seen in Nigeria [8, 9].Figure 4 is an example of aneurysm of left brachiocephalic AVF fistula.

Stenosis

Stenosis of the vein following AVF creation is quite common. Implicated in the causes of stenosis are the surgical dissection with mobilization of the vein and the turbulent flow within a functioning AVF. The understanding of the classification would ensure appropriate referral and treatment. There are three types of stenosis namely: type I (anastomostic venous stenosis), type II (stenosis of the needling segment), and type III (junctional stenosis) [48].

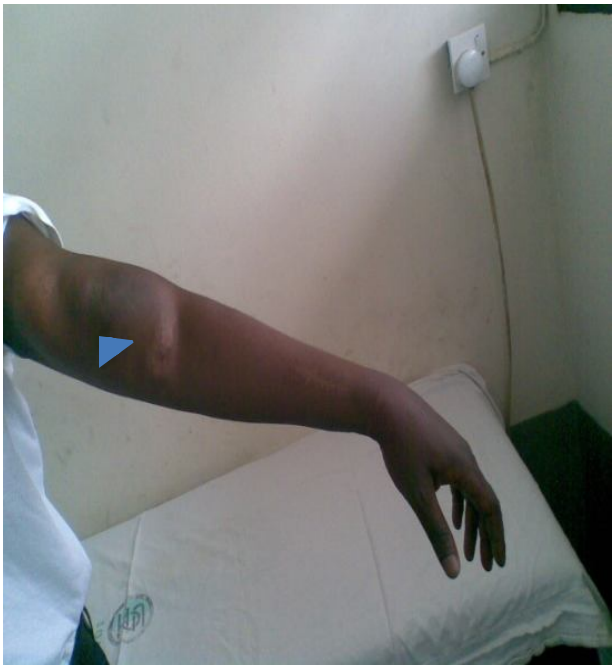

Fig. 4: Blue arrow head indicates the aneurysm of the left brachiocephalic arteriovenous fistula

***Note**: all the illustrations in the figures are from the patients managed at the University College Hospital, Ibadan.*

The treatment of type I and II stenosis include percutaneous transluminal angioplasty (PTA) but long term results is disappointing [49, 50]. Surgical thrombectomy with Fogarty catheter is useful. Others include distal stenotic vein ligation and proximal re-anastomosis of cephalic vein to radial artery. If segment of stenosed vein is long, saphenous vein interposition graft can be used [48].

Brachiocephalic AVF can be complicated with stenosis of the cephalic vein at its junction with the axillary vein. PTA with stenting should be done carefully because of the possibility of rupture. Surgical option is distal cephalic vein dissection and transposition to central basilic vein or brachial vein [48].

Thrombosis

The incidence of venous thrombosis complicating AVF varied from 10.8% in Nigeria [8]; 15.8% in Europe [49]; 18.1% in Iran [50] to 26.4% in Casablanca [39]. Thrombosis was common in ESRD patient was had RC-AVF than those who had BC-AVF, particularly patient above 50 years of age (p=0.034) [47] and those patient who were given erythropoietin (p=0.011) [51, 52].

The management of AVF thrombosis includes balloon dilatation, mechanical thrombectomy and use of pharmaco-mechanical thrombolytic agents. These options of treatment results in an overall fistula patency rates of 75% at 3 months, 65% at 6 months, 51% at 12 months, and 22% after 24 months [49].

Cost of AVF creation

The average cost of autogenous AVF creation in the major cities of Nigeria ranged from 330USD-645USD in an environment where the average income per month is about 129USD-258USD. In other to increase the number of patients with AVF usage for haemodialysis [7], our tertiary medical centre, has provided free AVF creation. In fact, government and non- governmental organizations should support patients with ESRD by subsidizing the cost of surgery and dialysis as was initially done in the United States.

In conclusion, autogenous AVF is a desirable long term access for ESRD patients, the success can be reduced in the presence of old age, cigarette smoking, obesity, diabetes mellitus and vascular occlusive diseases. Pre-operative, intra-operative, post-operative ultrasound vascular

Mappings and meticulous surgical technique will improve the success of primary radiocephalic AVF. More ESRD patients will benefit from the creation of AVF if the procedure cost can be subsidized by appropriate authority. The patient must be adequately educated about his disease, the values and likely complications of AVF and their management.

Authors' contribution

Takure A.O; Concept, design, initial drafts, review of literatureand update of literature, final write up.

Adebayo SA; Design, review of literature, initial drafts and final write up

Shittu O.B; Design, review of literature, critical review of all drafts and final write up

Salako B L; Concept, critical review of drafts and final write up

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