E-ISSN: 2616-3470
P-ISSN: 2616-3462

https://www.surgeryscience.com
2024; 8(2): 55-59
Received: 22-04-2024
Accepted: 04-06-2024

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Dialysis vascular access stenosis and its endovascular management

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DOI: https://doi.org/10.33545/surgery.2024.v8.i2a.1085

Abstract
One form of renal replacement therapy, dialysis mimics the kidneys' filtration of blood. Toxins, excess water, and solutes can be removed from the body with the use of artificial devices. Hemodialysis (HD) is the most common method for dialysis in Egypt caused by a higher potential for infection with peritoneal dialysis and due to wide availability of HD centers. Central venous catheters, either tunneled or non-tunneled, are very important in cases of urgent HD, temporary access till maturation of arterio-venous fistula (AVF) that may take up to two months or in cases when AVF and arterio-venous graft (AVG) seem unsuitable or contraindicated. The two main ways in which arteriovenous fistulas and grafts are formed are by the direct connection of veins to arteries or by the use of a synthetic graft. This sets up a circuit with a high flow rate, which makes hemodialysis percutaneous cannulation easier.

Keywords: Central, percutaneous, cannulation, catheters

Introduction
Dialysis is a kind of renal replacement therapy that involves the artificial removal of excess water, solutes, and pollutants from the blood by the use of machinery that mimics the kidneys [1]. Dialysis is a process that uses two mechanisms—diffusive clearance and convective clearance—to remove solutes from the body by passing them through a semipermeable membrane in response to a concentration gradient [1, 2].
Creation of vascular access is essential for hemodialysis (HD), so to make efficient dialysis, vascular access must provide an adequate flow rate with long durability and less risk for complications. The three vascular access options for HD at present are arteriovenous fistulas (AVFs), arteriovenous grafts (AVGs), and central venous catheters (CVCs) [3].

Hemodialysis Access
CVCs: Either tunneled or non-tunneled, are very important in cases of urgent HD, temporary access till maturation of AVF that may take up to 2 months or in cases when AVF/ AVG seem unsuitable or contraindicated [4].

Advantages of CVC: Such include having access right away, not having to use needles, and being able to move about easily while having dialysis. However, there are several complications from usage of CVCs like higher incidence for infections, short-term durability and the most common complication is central venous stenosis that leads to difficult future vascular access [5].

AVFs and AVG
Selection of fistula type
To create an AVF, surgeons surgically join two veins, either in their natural locations or by moving the vein's distal end closer to the skin for simpler cannulation. Translocation entails moving the vein in its entirety before the anastomosis is carried out [6].
For the most part, these kinds of connections are made with the upper limb; where possible, the non-dominant upper limb is used for AVF development. A greater quality of life and continued daily practice are guaranteed with this strategy, which also gives the dominant limb enough time to mature vascular access, also self-needling is easier to teach for those self-caring in hospitals or those receiving HD at home [7]. (Figure 1).

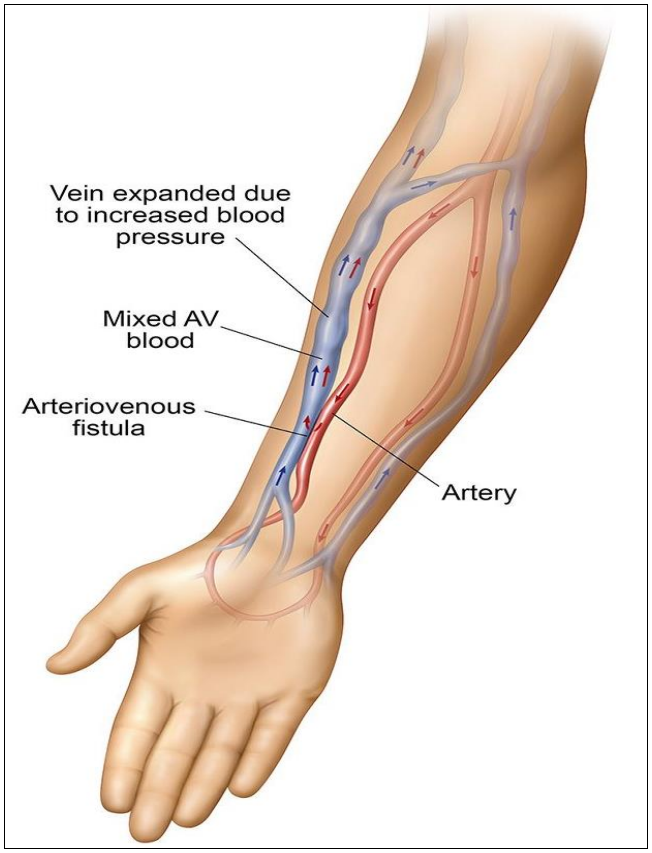

Fig 1: Distal AVF (radio cephalic fistula) [8]

Choice of vein and artery for AVFs creation

According to the European Society for Vascular Surgery (ESVS) careful preoperative evaluation of a vein and an artery using duplex ultrasonography (DUS) or angiography in some cases is very important in choice of an adequate artery and vein for AVF creation hence AVF maturation. Therefore, physical examination of venous access is a crucial aspect of patient care, and it can be challenging to establish venous access in some individuals. So, rapid bedside assessment is essential to identify patients who are at risk of difficult venous access and to guide the choice of an appropriate vein and artery. In a short amount of time and with no special tools required, this evaluation can be carried out right at the patient's bedside. Though it's true that a quick bedside evaluation can yield a lot of useful information, many patients still need more. When deciding on the best vein and artery access, it is important to consider not only the patient's specific medical needs but also their medical history, the results of any necessary physical examinations, and any relevant imaging investigations [9].

AVFs configuration

Because it is easier to approximate the vein and artery with an end-to-side AVF anastomosis and because it reduces the risk of distal venous hypertension without compromising patency, this arrangement is preferred over a side-to-side one [10].

AVGs

Over the last decade, there has been an increase in the use of prosthetic AVGs, which are known as secondary access options [11]. However, when contrasted with autogenous AVFs, AVGs still show lower rates of main and secondary patency. Although AVGs typically have high blood flow rates immediately after implantation, these rates often decrease as a consequence of neointimal hyperplasia (NIH) growth at the graft-vein anastomosis junction. This leads to stenosis, compliance mismatch, and final occlusion [12].

Risk of infection, thrombosis, stenosis, and low blood flow is more common in AVGs than AVFs So, in comparison to AVGs, the AVF is the better long-term vascular access option since it lasts longer and requires fewer maintenance interventions—that is, "if" the AVF grows sufficiently for hemodialysis, of course [13].

Maintenance and Complications of AVF

Physiology of functioning AVF

Within the first twenty-four hours after a fistula is opened, the flow from the artery to the vein begins to surge rapidly due to a cascade of events that impacts the wall structure, shear stress, and the overall flow rate. It usually takes around 8 weeks after providing the vascular access to see a significant increase in vein diameter and flow [14, 15].

Although AVFs aren't usually functional right away, these modifications allow the fistula to get ready for cannulation in due course. Mature refers to this process [16].

Definition of a mature AVF

A mature AVF is one that has developed adequate flow, wall thickness, and diameter, and is suitable for cannulation [17].

The following are some of the key factors that determine the maturation of an AVF

- **Adequate blood flow:** The AVF should have a consistent and adequate blood flow to support hemodialysis and withstand the increased pressure associated with it.
- **Venous diameter:** Even with a tourniquet, the AVF's venous section need to be at least 6 mm in diameter and have clearly defined borders.
- **Venous depth:** The venous segment of the AVF should be less than 6 mm deep.
- **Venous blood flow:** The venous segment of the AVF should have a blood flow greater than 300 mL/min. The vein should have a 6 cm area suitable for cannulation.
- **Minimal stenosis:** The venous segment of the AVF should not have any significant stenosis or thrombosis.

For the AVF to remain patent and functional over the long term, regular monitoring and follow-up are essential [18].

For an AVF to be considered functional, it must have undergone two successful cannulations throughout a minimum of six 30-day hemodialysis cycles [9]. The chance of VA failure due to thrombosis or external compression from hematoma, caused by injury to the thin wall of the newly arterialized vein, increases with premature needling. The likelihood of AVF failure appears to decrease with maturation timeframes greater than 30 days, on the other hand [15].

Access care before cannulation

Pre-cannulation examination

Thoroughly inspecting, palpating, and auscultating the VA before each HD session is necessary before cannulation [19, 20].

Skin preparation

Before cannulation, make sure the access sites are clean and free of infection by following strict aseptic procedure [21].

Anesthesia

Topical creams containing lidocaine 2.5% and prilocaine 2.5% are examples of anesthetics that can be used for needle

insertions; these creams minimize the sensation of discomfort [22].

Cannulation

The cannulation technique, in addition to the integrity of the blood arteries and surgical methods, determines how long a vascular access (VA) will last. The longevity of fistulas can be improved with the use of correct cannulation procedures [19].

Duplex-guided cannulation has the potential to shorten the time it takes to start hemodialysis and decrease the occurrence of local cannulation-related problems by increasing the success rate of cannulation for difficult AVFs. On the other hand, controlled studies comparing duplex-guided and unaided cannulation are necessary [21].

Access care after needle withdrawal

Removing the needles at the same angle as they were inserted is crucial for protecting the vascular access (VA) and achieving good hemostasis. The skin and the graft or vessel wall should be gently compressed at the needle exit sites after removal. In most cases, a hemostatic dressing and a two-digit method are used for this [9].

Prophylactic antibiotic

In various vascular surgical procedures, a number of randomized trials have demonstrated that administering broad-spectrum antibiotics prior to surgery reduced the occurrence of wound or graft infection by around 70% [23].

Exercise

Significant dilating of the outflow veins, an increase in vein diameters, and VA flow are all outcomes of hand-arm workout programs initiated after AVF formation [24].

Antiplatelet and anticoagulant

Although anticoagulants and antiplatelets can decrease AVF thrombosis by 44% following VA formation, they do not improve HD compatibility or maturation, according to several meta-analyses and systematic reviews [25].

Complications of AVF in renal patients

Maintenance of AVF in patients with ESRD is important to preserve future access options. Repeated access to the circulation in HD patients may lead to many complications that need re-hospitalization of the patients thus, increasing the burden on HD patients and hospitals. So, early detection of complications such as: AVF stenosis, thrombosis, bleeding, infection, aneurysm/pseudoaneurysm, seroma, steal syndrome, venous hypertension, neuropathy and cardiopulmonary complications [26].

Aneurysm

True aneurysm: is known as dilatation of the wall of the vein three times the diameter of the mature native vessel caused mainly due to repeated venipuncture at the same site of the vein during dialysis and mostly managed surgically by repairing the aneurysmal part and involves all layers of the vessel wall (Figure 2) [27, 28].

Fig 2: Aneurysmal fistula with a shiny central erosion [29]

Pseudoaneurysm: Is known as hematoma connected with vessel lumen mainly at puncture site or site of the anastomosis and after period it will be surrounded by a fibrous capsule. It occurs primarily after infection or prolonged bleeding from puncture site [30]. It is mainly presented as a ruptured fistula and in this case the fistula is ligated as a lifesaving maneuver. In least emergent cases, endovascular intervention may be done like inserting coated stent to rule out the aneurysm [31].

Thrombosis of arteriovenous fistula

Thrombosis in AVF is a significant complication that can occur in patients undergoing hemodialysis. AVF thrombosis refers to the formation of blood clots within the AVF, leading to impaired blood flow and potential access dysfunction [32]. If the VA to be preserved, treatment must be started no later than 7 days after diagnosis. Delays in intervention increase the risk that the thrombus will progress and adhere to the vessel wall. Thrombectomy may become more difficult and less effective as a result of endothelial damage [33].

Risk factors for AVF thrombosis

The occurrence of AVF thrombosis is associated with a number of known risk factors. Age, diabetes, hypertension, obesity, smoking, and preexisting vascular disease are all examples of patient-related variables. There is an increased risk of thrombosis linked with AVF-related variables such as inadequate fistula maturation, stenosis or narrowing of the channel, and poor blood flow rates [33].

Venous hypertension

It is caused mostly due to central venous stenosis or occlusion (primarily by CVCs placement) and is diagnosed as gradually painful swelling and hyperpigmentation of extremity accompanied by engorgement of superficial veins (Figure 3) [34].

Vascular steal syndrome

One of the risks of making a fistula to get access to hemodialysis. It considerably reduces blood flow and pressure to

the affected tissues and produces numbness, pain, cyanosis of the fingertips, coldness, and weakness in the hands. It has the potential to cause gangrene, the death of tissues, and the amputation of digits in severe instances [31].

Infection

The leading cause of mortality in HD patients is cardiovascular illness, followed closely by VA infection, the most common kind of infection in this population. When it comes to infections, CVCs are the most prevalent, AVGs are second, and AVFs are the least common [9].

Hemorrhage

Normal coagulation tests and platelet counts do not explain the increased bleeding tendency and aberrant bleeding periods observed in hemodynamically-stabilized individuals.

To reduce exposure to the heparin used to prevent clotting in the HD circuit, it is recommended to schedule VA procedures on the day between dialysis sessions. In order to stop bleeding and keep VA functioning, quick action may be required in the early postoperative period. If the hemorrhage does not stop after digital compression, surgical revision may be necessary. To prevent infection or epidermal necrosis, it may be necessary to evacuate a clinically substantial hematoma that remains after bleeding has stopped [9].

Arteriovenous fistula stenosis

Concerns about the AVFs' maturation and patency have grown in importance as evidence of their greater use and development has accumulated around the globe. AVF is a A stenosis-induced insufficiency in dialysis or blockage of blood vessel pathways or loss of access is a real possibility; after a median lifespan of 3–7 years, nearly half of all fistulas fail due to stenosis; and between 41 and 64 percent of all fistula stenosis occurs within 3 centimeters of the arteriovenous anastomosis [35].

Fig 3: Marked right arm swelling due to ipsilateral central vein stenosis [29]

To avoid stenosis of AVFs in hemodialysis patients, several measures should be taken as the following:

- Fistula creation technique: It is crucial to select an appropriate site and create the fistula using an optimal surgical technique. A systematic review suggests that radial-cephalic fistulas have a lower risk of stenosis compared to brachiocephalic or BB fistulas. Additionally, the use of continuous vessel dilatation during the surgery can help minimize the risk of stenosis [36].
- Monitoring and surveillance: Regular monitoring of the AVF is necessary to identify early signs of stenosis such as physical examination, Doppler ultrasound, and angiography are commonly used for surveillance. A study recommends monthly Doppler ultrasound for the first three months after AVF creation, and then every three to six months thereafter to detect any stenosis [37].
- Blood pressure control: Hypertension can contribute to AVF stenosis. Maintaining adequate blood pressure control is crucial to prevent stenosis. A retrospective study suggests that strict blood pressure control and the use of antihypertensive medications reduce the incidence of AVF stenosis [38].

Treatment of vascular access stenosis

There are several treatment modalities available for vascular access stenosis. These modalities aim to restore blood flow through the narrowed or blocked blood vessels in order to maintain effective hemodialysis.

Percutaneous Transluminal Angioplasty (PTA): PTA is a common treatment modality for vascular access stenosis. It involves the insertion of a catheter with a balloon at the tip into the narrowed area of the blood vessel. The balloon is then inflated, which compresses the plaque and widens the vessel lumen. This improves blood flow and restores vascular access function. PTA has shown to have good short-term success rates, but long-term outcomes may vary [39].

Conflict of Interest

Not available

Financial Support

Not available

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How to Cite This Article
Hassan ST, Saleh AAN, El Attar AA, El-Barbary AH. Dialysis vascular access stenosis and its endovascular management. International Journal of Surgery Science. 2024;8(2):55-59.