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Review on Arteriovenous Fistula Techniques and Complications

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ABSTRACT

The purpose of long-term vascular access is to provide repeated access to the circulation with the least adverse effects. An arteriovenous fistula is the most preferred vascular access for the initial choice of chronic hemodialysis access. This is because it is favorable for long-term use and consistent with patients' characteristics and preferences. Moreover, it is easy to create and accompanied with minimal complications. The formation of the AV fistula necessitates adequate arterial and venous anatomy, as well as ample time for the AV fistula to mature before being used. Continuous monitoring is important to assess the functionality of AV fistula and to identify and treat associated complications. We aimed to review the literature for the different types of arteriovenous fistula, and the procedure and techniques in creating them. We also focused on the complications associated with arteriovenous fistula. Articles were chosen from the PubMed database, and selected studies were subjected to a thorough review. Patients with end-stage renal disease rely on hemodialysis for survival. For hemodialysis, there are various types of vascular access. An arteriovenous fistula is one of these, and it can be placed in a variety of locations. The decision to use an AV fistula should be individualized based on the patient's characteristics and physical evaluation. Moreover, continuous monitoring is crucial to promote the function of this vascular access.

Keywords: Arteriovenous fistula, Vascular access, Vascular mapping, Complications, Steal syndrome.

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INTRODUCTION

Continuous vascular access for hemodialysis is a critical procedure in the treatment of patients with end-stage renal disease (ESRD). An arteriovenous fistula is a surgically made connection between an artery and vein, to make a specialized vein that blood can be removed from and passed through the dialysis machine for filtering wastes. There are different access points in the body where the fistula is placed. Moreover, there are different types of vascular access used [1]. In this article, we focus on the different sites of arteriovenous fistula and their techniques in creation. Moreover, we mention the complications that accompany them. We also describe other types of vascular access.

MATERIALS AND METHODS

We utilized the PubMed database for the selection process of relevant articles, and the following keys used in the mesh ((“Mesenteric Ischemia"[Mesh]) OR (“Pathophysiology"[Mesh] OR "Diagnosis"[Mesh] OR "Evaluation"[Mesh] OR "Treatment"[Mesh])). For the inclusion criteria, the articles were selected based on including one of the following: Mesenteric ischemia or Mesenteric ischemia’s pathophysiology, diagnosis, evaluation, and treatment. Exclusion criteria were all other articles that did not meet the criteria by not having any of the inclusion criteria results in their topic.

Review

There are three main types of vascular access, which are arteriovenous (AV) fistulas, AV grafts, and central venous catheters [1-3].

Arteriovenous fistula

It is an acquired type of fistulas, surgically made for hemodialysis. The connection is created between an artery and vein, allowing blood to flow directly from the artery into the vein, hence raising blood pressure and blood flow via the vein. As a result, the vein enlarges, enabling it to deliver the amount of blood flow required for a sufficient hemodialysis session [1]. Upper extremity is usually preferred over lower extremities as an initial access site [4-6]. There are three common sites for this vascular access. The radio-cephalic fistula is created at the forearm by anastomosing radial artery to the cephalic vein. It is the preferred fistula for initial access for dialysis by vascular surgeons. The second site is the brachio-cephalic fistula, which is an upper arm fistula created by anastomosing the brachial artery to the cephalic vein [7]. The third type is a brachial-basilic transposition, another upper arm fistula, created by connecting the brachial artery to the basilic vein after transposing the basilic vein laterally and superficially to make it accessible for dialysis cannulation [8, 9].

Arteriovenous grafts

This type of vascular access is made by interposing a graft between an artery and vein. The grafts are made of expanded polytetrafluoroethylene (ePTFE) with a diameter ranging from 4 to 8 mm. Allografts are also used as an access conduit [10]. Common sites for AV grafts include the forearm, in which the radial artery is connected to the brachial artery by a graft configured in a straight form. Another forearm site is access connecting the brachial artery to either cephalic or brachial vein by a looped-configured graft. Upper arm sites include the brachial artery connected to the axillary vein by a straight-configured graft. The second site is a looped upper arm graft connecting the axillary artery to the axillary vein. There are also early cannulation arteriovenous grafts (ecAVGs) that can be used within 24 hours of graft creation [11].

Central venous catheters

This access consists of dual-lumen catheters made from polyurethane, silicone, or silicone composites, with lumen size ranging from 14 to 16 French, and a Dacron cuff. The catheter is inserted into the internal jugular vein and tunneled through a tract under the skin to the exit point where the cuff is placed [12].

Advantages of arteriovenous fistula

The goal of chronic hemodialysis access is to provide adequate blood flow and be repeatedly accessible for long-term use with minimal complications. Generally, AV fistula is preferred over other types of vascular access as initial access in newly-diagnosed patients [3]. Advantages of AV fistula include easy creation, as they can be created in the operating room, and sometimes in the procedure room, under local anesthesia or regional nerve blocks [13]. This is true for simple fistulas such as radiocephalic or brachiocephalic fistula; however, Brachiobasilic fistula needs more extensive surgery as they are located deep in the upper arm and require superficialization, and thus must be performed solely in the operating room under general anesthesia or regional nerve block [14]. Other advantages of AV fistulas include good blood flow for dialysis, and they last longer than other types of vascular access. Furthermore, matured AV fistulas are associated with the lowest adverse effects rates, and patency of an AV fistula can be maintained with fewer secondary procedures [15].

Prerequisites for AV fistula use

Several requirements should be met for the use of AV fistula. Firstly, for the site, the forearm fistula should be placed on the volar side, and the upper arm fistula should be placed on the anterior or lateral side. Moreover, it needs to be suitable for repeated cannulation, and it must be accessible while the patient is seated comfortably. Additionally, it must be placed in proximity of skin surface about 5 to 6 mm. Lastly, and most importantly, it should be efficient to provide adequate blood flow for dialysis sessions of at least 500 to 700 cc/min [16].

Evaluation

The physical examination aims to determine which anatomy is appropriate for the formation of an AV fistula. The optimal preoperative plan is to complement physical examination with vascular mapping using duplex ultrasound [17]. Ideally, the criteria for vein diameter appropriate for fistula creation is a minimum of 2.5 cm 2.5 mm under tourniquet at a warm room temperature. When planning the formation of an AV fistula, the non-dominant arm should be prioritized so that the patient can use the dominant hand freely [18].

It should be noted that AV fistula needs time to become mature before commencing chronic hemodialysis. The minimum period for maturation is four weeks [19]. However, there are as well several events such as medical workup, surgical referral, surgical assessment, and scheduling that take time, increasing the lead time to 6-12 months [20]. Some studies have shown that AV fistulas placed at least four months before hemodialysis were linked to a decreased incidence of sepsis and mortality [21].

Procedure

The creation of AV fistula can be facilitated using local anesthesia or regional nerve block [22]. Some studies suggest the use of brachial plexus block over local anesthesia. It should be noted that regional anesthesia causes vascular dilation which improves patency. Nevertheless, the advantage of this effect should be weighed with the risk of this type of anesthesia. The regional nerve block is associated with hematoma formation and uremic patients' bleeding tendency [14, 23].

After the anesthesia takes effect, an incision is made along the course of the chosen vein. Branches of the vein are ligated and divided with a silk suture to allow mobilization of the distal part of the vein. Then, a horsely needle is used to cannulate the end of the vein, and a Ringer-lactate solution infused with heparin is infused to distend the vein while the proximal part is compressed. Once enough distention is achieved, the procedure continues with exposing the artery through a different incision. The end of the vein is approximated to the side of the artery through a subcutaneous tunnel, and both vessels are ligated utilizing a 7-0 to 5-0 monofilament suture in a running fashion [1].

One of the most common causes of fistula failure is stenosis, see **Table 1**. For instance, the juxtaanastomotic segment is the location of stenosis in the radiocephalic fistula [24, 25]. This can be prevented by using some techniques. One of these techniques is the piggyback straight line onlay technique (pSLOT). In this technique, the posterior aspect of the cephalic vein is connected side-to-side to the anterior aspect of the radial artery. Moreover, the outflow vein is dissected further in the subcutaneous tissue to attain a straight line [26]. Another technique is radial artery deviation and reimplantation (RADAR), in which the aim is to decrease the manipulation of the vein. After ligating the radial artery, the distal end of the artery is turned toward the cephalic vein and anastomosed to its side [27].

Table 1. Typical sites of stenosis for the three most common arteriovenous fistulas

Access type	Typical site of stenosis
Radiocephalic fistula	Juxtaanastomotic segment
Brachiocephalic fistula	Cephalic arch
Brachial-basilic transposition fistula	Proximal swing segment

Postoperative examination

After the formation of the AV fistula, examination of the fistula by the surgeon in charge must be carried out to assess for early surgical complications, such as ischemia, infection, limb swelling, and nerve compression. It is recommended that this examination be done within two weeks after the surgery. Afterward, assessment of physiological maturation must be done by a nephrologist no longer than four to six weeks following surgery [1].

Examination of fistula maturation

Physiological maturation means that the vessels have undergone remodeling to increase the lumen area. Physical examination alone is appropriate to assess maturity [28, 29]. In the examination, the physician assesses the depth, length, and diameter of the fistula and whether it can be cannulated or not [30, 31]. Palpation of the fistula is very important to detect pulse or thrill. Normally, the fistula has a soft and compressible pulse. The presence of hyperpulsatile means there is obstruction causing increased resistance downstream. Usually, a palpable thrill can be felt at the anastomosis which disappears when the outflow vein is compressed manually. However, if it persists, that indicates the presence of an accessory vein. If no pulse or thrill is felt, the fistula may be thrombosed or dead. This is an alarming sign that the fistula needs further evaluation and intervention to salvage it [1, 29].

Complications of AV fistula

Primary Failure and failure of maturation

Primary failure is defined as a fistula that has never been used for hemodialysis or fails within three months of use. The incidence of failure is influenced by several factors, and it differs by the type of AV access. The brachial-basilic transposed fistula has the lowest rate, followed by the brachial-cephalic, and finally, the radial-cephalic, which has the highest rate [32, 33]. Associated risk factors include old age, female gender, cardiovascular disease, diabetes, thrombophilia, and surgeon experience [34-37].

Failure of maturation is influenced as well by numerous factors related to hemodynamics, patient demographics, and clinical factors. Hemodynamic factors are the most crucial and these include the size of the artery and vein and adequacy of blood flow. Clinical factors also play a role, such as the existence of cardiovascular disease, pulmonary hypertension, diabetes, and obesity [38, 39]. Common causes of failure of maturation are stenosis and thrombosis [40, 41]. Frequent monitoring based on physical examination, flow measurements, or duplex ultrasound is essential to detect and treat the problem before it takes place [1, 42].

Local

Hemorrhage: Bleeding is uncommon with the AV fistula procedure. However, patients with platelet dysfunction may bleed minimally. This can be treated with desmopressin. Any surgical bleeding must be controlled with suturing, and minor bleeding can be stopped using hemostatic agents [43].

Infection: The majority of bacteremia in hemodialysis patients is sourced from vascular access. The most prevalent pathogens are Staphylococcus aureus and, less typically, Staphylococcus epidermidis. Bacteremia is common during cannulation, even when there is no AV access infection [44, 45]. Overall, the risk of infection from AV fistulas is quite minimal [46]. Pseudaneurysms, hematomas, intense itching and scratching at needle sites, and the use of fistulas as a track for drug abuse are all potential risk factors for AV fistula infection [46, 47]. Infection can be treated with the administration of broad-spectrum intravenous antibiotics, and if there is a collection it is treated by drainage. Guidelines recommend that the antibiotic therapy should be spanned for 6 weeks, as it is assumed the cause of bacteremia is endocarditis since AV fistula is seldom the main source of bacteremia [1].

Venous hypertension: Mild to moderate limb swelling is common after the procedure and subsides with time. However, a chronic increase in the venous pressure in the limb can occur due to venous valvular incompetency or central vein stenosis. The sequela of this problem is skin changes such as discoloration, ischemic changes, and access failure [48-50]. This problem can be detected before procedure using venography, which shows dilated chest wall veins [51].

Aneurysm/pseudoaneurysm: The presence of an Aneurysms or pseudoaneurysms AV fistula poses the fistula to complications such as hemorrhage, rupture, infection, skin erosion, and difficult cannulation. Raised venous pressure caused by central venous stenosis, repeated cannulation at the same place, and immunosuppression has all been proposed as possible causes of the aneurysm [52, 53]. For pseudoaneurysm, it is usually the result of repeated cannulation at the same site and can be prevented by rotating the sites of needle insertion [54]. Guidelines recommend the revision of AV access complicated by aneurysm if there is a high risk of rupture, the skin overlying the access is completely eroded, or if there are no accessible sites for cannulation [1, 55].

Neuropathy: Carpal Tunnel Syndrome is the most common neuropathy in dialysis patients. It is frequently caused by amyloid deposition leading to median nerve dysfunction [56, 57]. Furthermore, the access itself may play a part in developing this complication due to the extravasation of fluid or blood leading to nerve compression [57, 58].

Systemic

Steal Syndrome and Ischemic Monomelic Neuropathy: Due to the high blood flow through the fistula, the distal limb can face ischemic complications from the decreased blood flow it receives. One of these complications is dialysis access steal syndrome (DASS), which presents with painful, cold, sensory/motor diminished hand [59, 60]. Another rarer variant of this complication is ischemic monomelic neuropathy (IMN). It presents with severe hand pain related to nerve ischemia [61]. Guidelines recommend the closure of the fistula once IMN is diagnosed [1]. AV fistula ligation for severe ischemia, banding to restrict flow in the high-flow AV flow, and interventions to increase distal blood flow in the low- or normal-flow AV fistulas are all treatment choices for DASS [62-64].

Pulmonary hypertension: incidence of pulmonary hypertension is high in patients with chronic kidney failure, and it is considered a comorbid disease in this population. The incidence is even higher among patients with AV fistula. Thus, it should be addressed and treated appropriately [65, 66].

Heart Failure: heart failure is rare in patients with AV access, even in the presence of underlying cardiac dysfunction. However, studies have shown that the creation of an AV fistula may worsen preexisting left ventricular hypertrophy [67-69].

Malignancy: Angiosarcoma has been reported at the site of AV access to be rare. Symptoms include pain with or without a swelling that may ulcerate or bleed [70-72].

CONCLUSION

Hemodialysis access is the lifeline of patients with end-stage renal disease. There are several types of vascular access used for hemodialysis. One of these is an arteriovenous fistula and has different sites where it can be placed. They all possess parallel characteristics, and each has its pros and cons. The decision for applying an AV fistula should be individualized according to the patient's characteristics, and pre-dialysis evaluation is essential to improve the chances of providing a functional AV fistula. Furthermore, continuous monitoring is crucial to assess for the maturation and functioning of the fistula. Additionally, monitoring is important to identify and manage complications.

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