Vascular Access for Hemodialysis

Rodríguez Vidal Néstor*, Couto Emilio*, D´Amore Verónica*, Saccone Claudio**

* Vascular Surgery Department, Hospital Aeronáutico Central (Buenos Aires Capital City)
** Vascular Surgery Unit, Hospital Interzonal de Agudos “EVITA” (Lanús O., Buenos Aires Province)

Abstract

Introduction: We recount our experience in the creation of arteriovenous fistulae (AV fistula) for hemodialysis in the Vascular Surgery Departments of the Hospital Aeronáutico Central (City of Buenos Aires) and the Hospital Interzonal de Agudos EVITA de Lanús (Buenos Aires Province), during the period between January 2008 and December 2012.

Objectives: To show the different vascular access alternatives available for hemodialysis, to which purpose their history is reviewed, and the considerations to be taken into account are described in order to make a decision as regards their use, the different options, their indication, the precautions for each of them and the possible complications.

Material and Method: A total of 98 patients with chronic kidney disease, requiring dialysis treatment, were studied, on whom 145 vascular access for hemodialysis surgical procedures were carried out in the 4-year-period from 2008 up to 2012; literature on the subject was reviewed, including the experiences in different centers and of other professionals.

Results: An appropriate surgical vascular access was achieved in 95% of the patients; sometimes, it was necessary to use different techniques on the same patient due to occlusions or complications of the previous techniques.

Conclusions: The conclusion is reached about the importance of care when creating a fistula, and its care afterwards; this responsibility lies on the specifically trained personnel in charge of hemodialysis, since occlusions and the gradual exhaustion of vascular access options pose a challenge to the surgeon, his skill and variety of resources.

Keywords: Chronic kidney disease. Hemodialysis. Arteriovenous
Introduction

Those patients whose renal function is so altered that basic requirements are not met require the use of artificial filtration procedures that would supplement said deficiency. The latter can be acute in nature, when it occurs suddenly for very different reasons either primary or secondary to other kidney pathologies that trigger it, or start gradually due to the progressive deterioration of the kidney function, which will lead to the usually definitive and well known chronic kidney disease.

The mechanisms to filter and clean blood that a failed kidney cannot perform are replaced with a device including filtration membranes and specific osmolar solutions that rid the blood entering the system of the substances to be eliminated and thus it is returned optimized to the internal environment.

This procedure requires the entrance of an adequate blood volume, through a cannula connected to a system that allows fluid blood to leave the organism and finally return to the individual's circulatory system—this process is known as **hemodialysis**.

Another way to achieve filtration is utilizing the peritoneum as membrane, with the use of components and solutions of specific osmolarity, which are instilled in the abdominal cavity to carry out the blood clearing process and is known as **peritoneal dialysis**.

**BACKGROUND:** The first piece of information on the treatment of renal failure goes back to the German Doctor W. J. Kolff, who by the end of II World War, in 1944 carried out the first hemodialysis treatment, by means of a primitive filtration process which successfully cleaned the blood of patients with renal failure.

This original idea did not become widespread, and its delay was related to the impossibility to access the bloodstream repeatedly and for long periods in order to treat the blood.

It was only in 1960 that it spreads, and thus Scribner, Dillard and Quinton, an internist, a surgeon and an engineer respectively, designed the silastic external shunt, which was the most widespread and consisted of the cannulation of an artery and a surrounding vein which communicated with a connector. The radial artery and the cephalic vein at the wrist, or the foot pedis artery and the saphenous vein were used. After the hemodialysis, the system was kept patent in order to repeat the procedure. This is known as **external shunt** and was used until the beginning of the 1990s.

The limitation posed by the time to be used, as any exposed element, was solved by the creation of an anastomosis surgery between an artery and a vein. In 1966, Brescia and Cimino, observing the characteristics of a post-traumatic femoral AV fistula, which generated a dilation and superficial venous system flow increase, i.e., and arterialized vein, created this union between the radial artery and the cephalic vein at the wrist, which is still the most widely used procedure as indication for the creation of arteriovenous fistula for hemodialysis. This is known as the **Internal shunt**.
The creation of catheters and prosthesis, increasingly nobler for the function, is very new and will be developed in the present paper.

**Objectives**

Considering the case histories presented, setting out our own experience as vascular surgeons, with the responsibility for performing surgical procedures to achieve a vascular access, and the corresponding literature review, we list below the objectives pursued.

1. To gain a simple and easy vascular access for hemodialysis.
2. For the vascular access to allow a safe utilization, both for the patient and the member or sector where it is placed.
3. For the vascular access structure to be resistant enough to endure repeated punctures for a long time, considering the continuity of treatment.
4. To provide enough flow required by the hemodialysis machine suction system.
5. To be extensive enough so as to allow changing puncture points.
6. To present few complications.
7. To be comfortable for the patient, since sessions last several hours (3 to 4hs.), and puncture zone must be immobilized.
8. To be available before the beginning of hemodialysis, thus reducing the need to use central venous catheters.

**Material and Methods**

An análisis was carried out of patients with chronic kidney disease, requiring hemodialysis treatment, for which vascular access was necessary, at the Hospital Aeronáutico Central of the City of Buenos Aires, anda t the Hospital Interzonal de Agudos “Evita”, Lanús (Buenos Aires Province). Both hospitals shared the same health care responsibility but belonged to population groups with different social and economic realities. A total of 98 patients were found in the 4-year-period evaluated from 2008 up to 2012. Ages ranged from 14 and 82 years, with an average age of 60 years at the Hospital Aeronáutico Central and 45 years at the Hospital EVITA, 60% male patients.

Out of this total, native fistulae were performed in 80 patients (80%) as first option, while for the remaining patients the first choice was the use of prosthetic elements.

Patency of vascular accesses lasts from 24hs up to 48 months.

The reoperation requirement involved 65% of the patients, due to subocclusive processes, occlusive processes, hematomas, infections, which required the use of temporary catheters or the creation of a new AV fistula in a different anatomic sector, or the use of prosthetic elements.

Faced with the exhaustion of vascular access options, permanent catheters had to be used or the patient had to be referred for peritoneal dialysis, the latter were only 2 cases.

**Results**

Native fistulae were performed in 80 out of the 98 patients (80%) as first choice, while for the remaining patients the initial resource was the use of prosthesis, since the patients’ anatomical elements were unsuitable.

Patency of vascular accesses lasted from 24hs up to 48 months, during the period assessed.

65% of patients had to be reoperated, due to subocclusive processes, stenosis or hematomas,
occlusion or infection; in some cases, the latter required the eventual removal of heterologous prosthesis. Considering these contingencies, it was necessary to perform embolectomy procedures with the Fogarty catheter, to use temporary catheters, to create new fistulae in a different anatomical sector or the use of prosthetic elements. The exhaustion of vascular access options require the use of permanent catheters, which also have limited duration, in our experience not longer than 20 months, or the patient's final referral for peritoneal dialysis.

Discussion

In order to decide upon the appropriate procedure, a preoperative evaluation is carried out, considering the following priorities:

GENERAL EVALUATION:

- Obesity: it predisposes the use of prosthesis from the beginning, due to the difficulty in the access and the depth of the vein which, although it is dilated because it has been arterialized, is not easy to access.
- Diabetes: it requires a more thorough evaluation of the arterial system, due to the frequent calcinosis of distal arteries. Although this condition is not an absolute contraindication, it requires a more rigorous treatment of the artery.
- Heart failure: it is necessary to consider the possible imbalance resulting from the influence of peripheral resistance reduction and the increase of venous return that can be generated in a high-flow AV fistula, the more probable the more central the anastomosis.
- All kinds of infections must be excluded, since they can endanger the creation of the fistula.

LOCAL EVALUATION:

- Detection of arterial pulse, its characteristics and eventual control of the member blood pressure.
- Careful observation of the superficial venous system, using a proximal compression opening and closing the hand in order to to achieve venous distention, observe its trajectory and continuity, without areas where it is not present.
- To confirm its patency, with the segmental collapse maneuver followed by immediate filling.
- To consider fibrotic areas, consequence of previous phlebitis.
- Permanently distended areas which could show high resistance in evacuation.
- Presence of scar tissue in the area suggested for fistula creation.
- Local infections evidence or suspicion.
- Edema of the limb which could suggest infection, previously mentioned, as well as thrombosis of a central vein, even more so with a clinical history of repeated previous catheters.

COMPLEMENTARY TESTS:

Clinical evaluation is usually enough in the preoperative period. Vascular diagnostic methods using contrast material are generally harmful for
an already complicated renal function, thus their indication is very limited at this stage, but they are more frequently used in subsequent controls for dysfunction of a fistula in use.

We focus on the ECHO DOPPLER as complementary test, since it is completely noninvasive, does not require the use of contrast material, it is accessible in almost all centers, and economical as far as costs are concerned. The only objection raised is that it still depends on an operator.

Its indications would be:

- In case of obesity.
- Doubts as regards vein patency, partial thrombosis.
- Venous parietal features, calcifications that suggest difficulties in its development (dilation).
- Caliber with loop, ideally superior to 4mm.
- Venous continuity mapping in the complete path.
- As regards arteries, to evaluate their patency and possible subocclusions.
- Parietal characteristics, calcinosis, calcifications that require that other less compromised areas be chosen.
- Appropriate minimum caliber which should be more than 2 or 3mm in diameter.
- Evaluation of central veins, subclavian artery and internal jugular vein in cases with repeatedly-used catheters and edema or spontaneous vein dilations in the cervical region.

**VASCULAR ACCESS OPTIONS FOR HEMODYALISIS:**

In order to carry out the hemodyalisis, there are different ways to gain a vascular access, namely:

1. **Catheters**
2. **Arteriovenous fistulae:**
   a. Native fistulae
   b. Prosthetic fistulae:
      i. Autologous
      ii. Homologous
      iii. Heterologous

1. **CATHETERS:** They are malleable interna double-lumen tubes, which come with a puncture needle for insertion, a guidewire, essential for the success of the procedure, and a semirigid dilator to facilitate the definitive and softer path of the catheter in order to avoid intravascular decubitus complications.

They are absolutely useful for performing dialysis in acute episodes or emergencies. Technical evolution makes it possible to introduce them through a vein percutaneous puncture and access central venous trunks, and the procedure can be repeated even in the same area after some time. They differ from the first catheters described, which were inserted by open surgery, rendering the artery or vein definitively useless.

According to their features, they are divided into: **catheters used for short periods**, for emergent dialysis cases, transitory need or prior to the creation of a definitive arteriovenous fistula. It counts on common double-lumen, which divides externally into two separate access points, the arterial one for the blood suction function and the venous one for reintroducing already purified blood. The suggested sector for introduction is through the internal jugular vein, while it is advisable to avoid the subclavian access, since a venous thrombosis may occur as eventual complication which would difficult the creation of a
possible arteriovenous fistula on the homolateral limb of the thrombosed subclavian artery. As far as the femoral artery access is concerned, it is prone to thrombosis, which poses high risk of suffering a possible pulmonary thromboembolism. Catheters used permanently or semi-permanently, which enable their use for longer periods, their characteristic is that they are tunneled in the subcutaneous cell tissue from its entrance into the vessel up to its exteriorization for its access, i.e., as a counteropening. Bearing that in mind, they are longer, in a double-lumen catheter, or in most cases, in two individual catheters, like Tesio catheters, counting on a dacron cuff, near its exteriorization in the skin which protects the rest of the system from skin infections.

This type of catheters is chosen for elderly patients, or those whose vascular access options have been exhausted, or with limited life expectancy.

2.- ARTERIOVENOUS FISTULAE: It is the union of an artery and a vein, by means of a surgical anastomosis between them. They are divided into:

- AUTOLOGOUS: performed between an artery and vein of the patient, in any place where the arterialized vein is superficial enough so as to enable its easy puncture.

Thus, on the upper extremities, first choice and always the non-dominant one, the options are:

a) Wrist radio-cephalic AV fistula, which could be created as distal as possible from the anatomical snuff box or up to the proximal area on the forearm, whichever is the most suitable. It is the so called Cimino-Brescia fistula, when created on the wrist, and it is still the first choice considering its easy access.

b) Cubital-basilic AV fistula, exceptionally chosen since it is very uncomfortable to puncture and due to the increased sensitivity of the ventral lateral inner area where the basilica vein is found on the forearm.

c) Humerus-cephalic fistula, either direct or at the “M” or “H” formed at the confluence of superficial veins on the elbow ventral fold. In this last option, the possible leak and basilic arterialized vein must be taken into account, to the detriment of the cephalic vein development, in which case it could be ligated in order to avoid this situation or leave it free to develop as another option of use. It is of outmost importance to identify the perforating antebrachial vein,
constant in its location and which caliber is enough to represent a leak opposed to the expected development of the cephalic vein on the arm, thus the former should be ligated to favor the effect pursued.

d) Humerus-basilic fistula: in case the cephalic vein is unsuitable, the basilic vein should be chosen, of noble structure and caliber but with the great drawback that it soon deepens into the inner side of the arm, which difficults its puncture. Thus, the surgical superficialization of the basilic vein is necessary, which can be done together with the creation of the fistula or after it. A) In the first case, the vein is isolated in its trajectory using an incision on the inner side of the arm. Its proximal end is sectioned, and placed in cephalic vein territory, with spoke-like incisions and superficial tunneling, finally constructing the end-to-side basilic-humerus anastomosis. B) If it has been previously arterialized, the procedure consists in ligating its collateral veins, freeing it before it drains into the axillary vein, and by way of a longitudinal dissection of the subcutaneous cell tissue, and placing it more superficially and externally, near the cephalic vein territory.

An anatomic detail to bear in mind is the need to free the vein from the lateral brachial cutaneous nerve that “hugs” it in its section proximal to the axilla, which must be longitudinally sectioned in order to avoid injuring it.

When options of the upper extremities are exhausted, lower limbs offer the following:

a) Saphenous–femoral: creating a loop at the inguinal region, with good caliber and flow, but uncomfortable for the patient and presenting frequent infection complications.

b) Anterior or posterior tibial–saphenous, not widely used due to frequent occlusions.

- PROSTHETIC FISTULAE: The advantage of this option is its ready availability, but on the downside they are more prone to potential infections due to the repeated punctures.

When native fistulae have been exhausted, its option is not questioned. They are also considered for elderly patients, for whom the development and optimization for use of the arterialized vein is slower and sometimes, impossible to achieve.

The types of accessible prostheses are:

Autologous: the patient’s own internal saphenous vein, which we include in this group, but its development must be awaited as in the primary autologous fistulae.

Homologous: cadaveric biological prostheses, under experimentation with cryopreservation, which access is very burdensome, like the umbilical vein, still with no greater benefits than the other options.
Heterologous: Its features and calibers are constantly improving, with modified dracon, and the most widely used is the one made of expanded polytetrafluoroethylene or PTFE, which come in different calibers and shapes (straight or tapered). The PTFE prostheses are still the noblest for the desired function, they have good flow preservation, higher resistance to eventual infections and better tolerance to repeated punctures.

Premises to be borne in mind:
- First chose the non-dominant arm.
- Give priority to more distal areas in order to save central veins in case of failure of the previous option, which is impossible otherwise.

There is a wide variety of options for implant and, sometimes, the **surgeon’s creativity** is tested, in cases of multiple previous fistulae.

The most frequent options are:

1. Forearm loop, where arterial anastomosis is constructed either on the humerus artery or at the commencement of the radial artery, through a longitudinal incision on the internal border of the biceps tendon, its subcutaneous trajectory runs on the forearm palmar side, through spoke-like incisions, to finally construct the vein anastomosis in the surrounding area of the artery, at the “M” formed at the confluence of superficial veins, on the fittest vein. Unlike the native fistula, the already described **patency of the perforating vein should be preserved**, due to its anatomical constancy and good caliber for optimal vein drainage.

2. Humerus-axilllary fistula, with subcutaneous trajectory in the area of the cephalic vein, which could be extended to subclavian artery territory.

3. Loop fistula: femoro-femoral fistula at the inguinal region, preferred option when faced with limited choice of upper extremities, with good flow but uncomfortable for the patient and with frequent complications of infection due to the anatomical region.

4. Other less frequent options include: crossed subclavian subclavian fistula on upper
Thorax, with large flow, careful of an eventual compromise of heart function, the use of the artery per se and renal vein with prostheses superficialization, which entails a really major surgery on a patient in critical condition. It is necessary to consider an axillary (arterial)-femoral (venous) bridge, for patients with occlusive processes of the upper venous tree; other options could be described according to the possibilities and the attending surgeon’s experience.

Complications

Stenosis: Dysfunction of the hemodialysis, which could occur on autologous, at the puncture sites or anastomosis, and on prosthetic in general on the venous anastomosis or subsequent to it. Diagnosis with Echo Doppler, fistulography using contrast material are useful to decide the features and administer treatment, which could be surgical, endoluminal, or with stent.

Occlusion: Absence of heart murmur and pulse, of early resolution, sometimes with a simple thrombectomy procedure with the Fogarty catheter.

Steal syndrome: The decrease of the extremity perfusion distal to the arterial anastomosis, it can be expected and generally compensates spontaneously, but sometimes its symptomatic persistence requires surgical treatment by which the arterial anastomosis is narrowed, with eventual risk of affecting the fistula itself.

Infection: the usual symptoms and its eventual general compromise require treatment with antibiotics, with a previous blood culture. Sometimes, the fistula cannot be temporarily used which requires the use of catheters, or the removal of the former, generally when a heterologous prosthesis is infected.

Aneurysm or Pseudo-aneurysm: Repeated punctures and prostheses wear and tear generate weakness zones, which translate into dilation with the evident risk of eventual bleeding; this requires surgical treatment to replace the sector involved. In those cases where dilation is thrombosed, pressure ulcers may occur or it can cause an aesthetic problem, which requires its resection.

Increased flow: Overdilation may entail a flow rate range which may, sometimes, provoke heart failure symptoms.

Conclusions

The variety of options is clear evidence that they can become exhausted due to occlusions or infections which require their removal, hence the utmost care in choosing the access, in its creation and its preservation care afterwards, which is linked to the experience of personnel in charge of the repeated punctures for hemodialysis treatment.

It is important to give priority to native access options, observe difficulties and advantages presented by each sector, as described in each of them. This tests the attending vascular surgeon’s ability, and is a challenge to his skills and creativity. It must be borne in mind that being creative is not improvising— the decision must be carefully thought out or consulted, or both, since repeated failure involve the individual responsible for the decision.

References


