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**AN EBOOK ON  
VASCULAR DISEASES**

# A.V Access Dysfunction

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## The aim of the review

The aim of this review is to highlight the most important complications of A.V access which causes a socio-economic burden and need hospitalization with 36-39% of admissions related to dialysis access [1].

## Introduction & epidemiology

End Stage Renal Disease (ESRD) is associated with severe morbidity, mortality, high cost for management and different impacts on general health [2].

Incidence of ESRD is on the increase worldwide at an annual growth rate of 8%, far more than the population growth rate of 1.3% [3].

According to 9th Annual Report of The Egyptian Renal Registry provided by Egyptian Society of Nephrology and Transplantation (ESNT), prevalence of ESRD in Egypt raised to 483 patients per million [2].

Despite an increase in the number of kidney transplants in the world, which is the best treatment of ESRD patients but in Egypt hemodialysis represents the main mode of treatment [4].

Arterio-venous access includes a native arterio-venous fistula (AVF) and an arterio-venous graft (AVG) [5].

## Functioning of A.V access

**The criteria for successful maturation or functioning of fistula was defined as:**

Suitable for repeated puncture, successful dialysis > 4 hrs. Through fistula on 3 or more consecutive occasions, and a fistula, which provides minimum blood flow of 300 ml/min or more for 4 hrs [6]?

**The K-DOQI (Kidney- Dialysis Outcomes Quality Initiative) Guidelines define the Functioning A.V access by:**

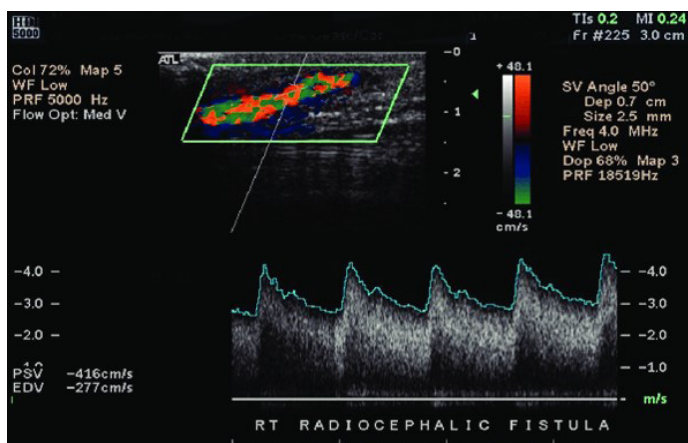
A flow volume of >600 ml/min, an out-flow vein diameter of  $\geq 6$  mm, and an out-flow vein depth of  $\leq 6$  mm below the skin surface [7].

## Functioning A.V access regarding the US criteria

Vein is larger than 4 mm and blood flow is greater than 250-500 mL/min through the fistula [8].

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**Figure 1:** US image denotes functioning radiocephalic fistula with accepted PSV (416 cm/s) [9].

Preoperative vessel assessment with ultrasonography enhances the success of creation and outcome of AVF[10].

**The most widely mentioned recommendation is:**

Artery diameter  $\geq 2$ mm, Vein diameter  $\geq 2.5$  mm, Proximal artery EDV  $\geq 24.5$  cm/s to avoid AVF thrombosis, and the draining veins as the subclavian vein are patent, lastly the arterial tree distal to the AVF should be examined to avoid steal syndrome [11].

After anastomosis construction, an increase of flow (10–20 times), vessels dilatation is necessary to be functional [12].

**Mechanism of access failure**

Venous outflow stenosis, arterial inflow stenosis, and cannulation location [13].

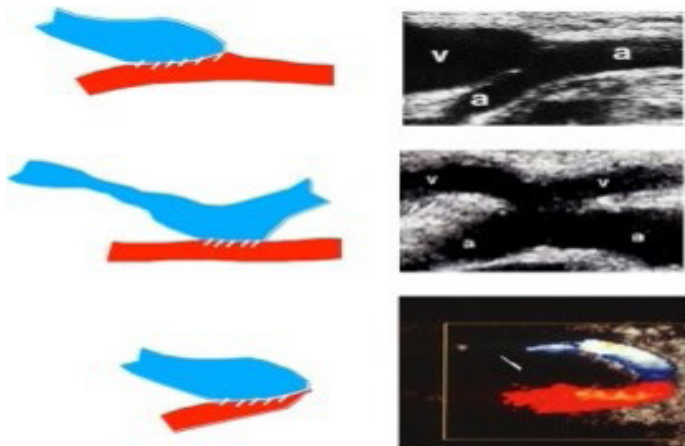
**Causes of dysfunction A.V accesses**

**Pre-surgical factors include**

Female sex, Obesity, Diabetes, Age, Cardiovascular disease [14].

**Surgical technique for anastomosis includes**

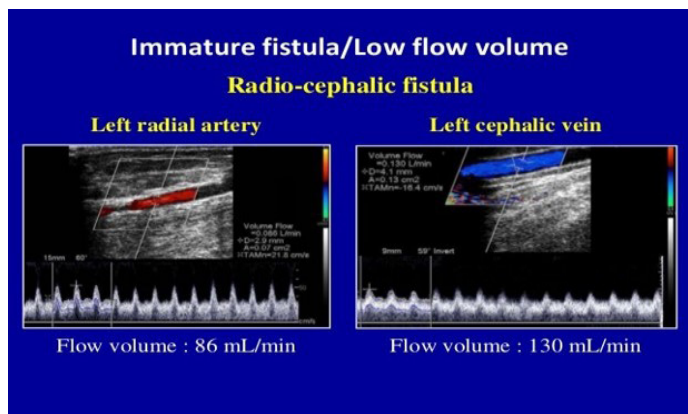
End-to-end anastomosis can lead to ischemia of the distal extremities, especially in the elderly and patients with diabetes mellitus, Side-to-side anastomosis is technically easier and can be done if the blood vessels are close to each other but may lead to development of venous hypertension, and currently, the most acceptable option is end-to-side anastomosis.



**Figure 2:** US imaging can differentiate between the types of access anastomosis [15].

**Immediately after surgery**

Hemorrhage, and Low venous flow or hematoma may occur [12].



**Figure 3:** Postoperative radio-cephalic fistula with low flow volume diagnosed by duplex US [16].

**At a later stage**

Infections, aneurysmal formation and/or false aneurysm, fistula vein stenosis, congestive heart failure, steal syndrome, ischemic neuropathy, thrombosis and venous hypertension [17].

**Infections**

Infection accounts for 20% of all AVF complications, which is manifested as localized erythema and edema and is usually easily treated. Much more serious is an infection associated with anatomical abnormalities, such as aneurysms, hematomas or abscesses, which require surgical intervention [18].

**According to (2018) Clinical Practice Guidelines of the European Society for Vascular Surgery (ESVS)**

An AV graft is more likely than an AV fistula to have problems with infection [19].

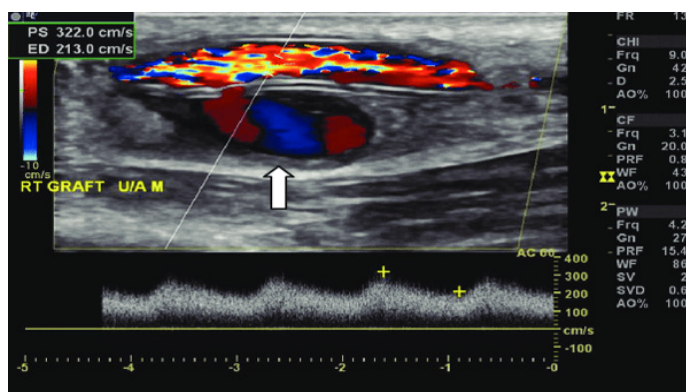


**Figure 4:** Skin infection and ulceration over aneurysmal A.V fistula [17].

**Aneurysmal formation**

An aneurysm is a pathological enlargement of the blood vessel wall resulting from repetitive puncture, false aneurysms are hematomas located outside the vessel wall, formed due to a leaking hole in the artery, most often due to iatrogenic trauma [20].

Surgical intervention is recommended when there is a risk of perforation, ulceration and bleeding [21].



**Figure 5:** Duplex US image showing pseudoaneurysm outside the fistula [22].

### Stenosis

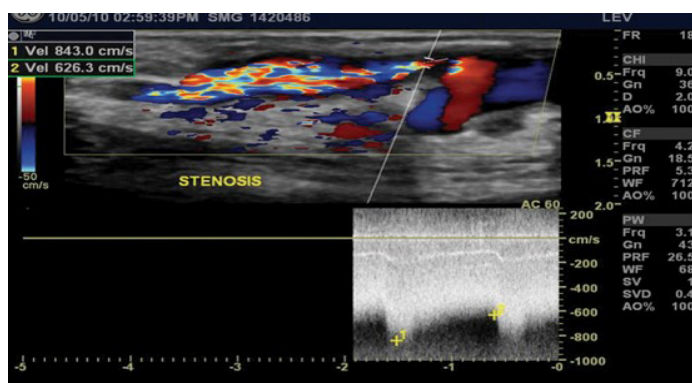
Significant stenosis in the site of anastomosis or fistula vein lumen define as; a reduction by more than 50% vascular endothelium [23].

Uremic factors such as homocysteine or endogenous inhibitors of NO synthase (as in patients with ESRD), in addition to the impaired vasodilatation of the vessels due to endothelial dysfunction lead to reduced venous distensibility [24].

Also vein wall dispensability is controlled by collagen, elastin and smooth muscle and when collagen fibers are accumulated in place of smooth muscle cells in pre-access cephalic veins, causing a decrease in the elasticity of the vein wall. This process reduces the functional properties the vessels, and thus interferes with the proper maturation of the AVF [24].

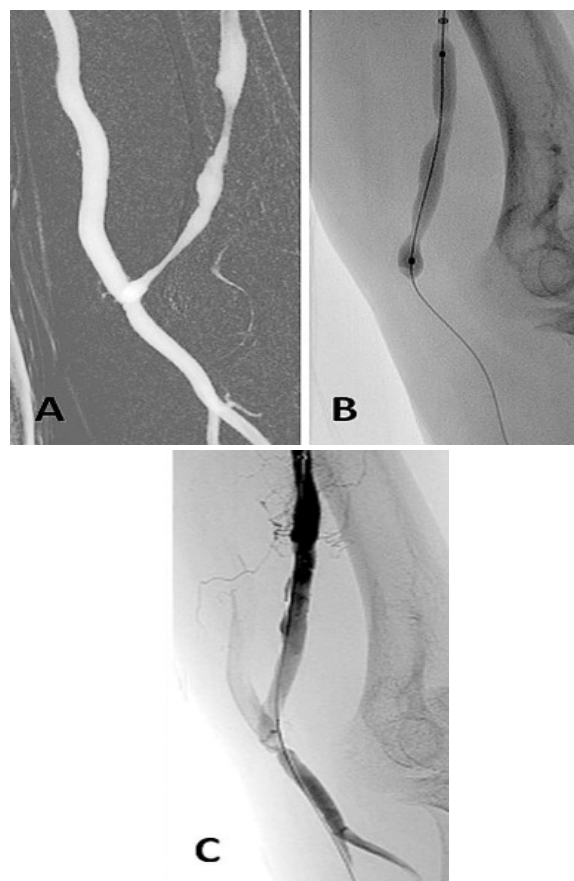
Clinical suspicion of stenosis is confirmed by the presence of several factors: Reduced quality of dialysis, problems with puncture, such as prolonged bleeding after AVF puncture [12].

Stenosis was diagnosed by Doppler ultrasound when there were reduction of the vessel diameter of more than 50% and an increase in PSV ratio greater than 2: 1 in the draining vein or greater than 3: 1 in the anastomotic area [25].



**Figure 6:** Color duplex US shows an increase in PSV (843 cm/s) which indicate stenosis [26].

Treatment involves balloon dilatation of the stenosis, stent implantation or surgical revision. Percutaneous transluminal angioplasty (PTA) in the treatment of vascular access stenosis improves fistula function and prolongs fistula survival in patients with shorter lesions (<1 cm), but restenosis remains the major problem [27].



**Figure 7:** Angiogram of balloon dilation to brachiocephalic access stenosis [27].

### Impact of AVFs in Heart Failure

Cardiovascular complications are the leading cause of death in patients on HD, and LVH is the most common cardiac change in patients with ESRD. Development and progression of LVH in HD patients is complex and often multifactorial; include volume overload, creation of an AVF, anemia and pressure overload. LVH is an adaptive response to increased cardiac workload [28].

### Arterial steal

Reversal of flow in inflow artery distal to anastomosis, blood flow to the hand is decreased. More common in AVG than an autogenous AVF [17].

### Staging

- I. Mild pale, blue or cold hand without pain.
- II. Moderate pain during exercise or hemodialysis.
- III. Severe pain at rest.
- IV. Limb threatening with ulcer, necrosis, or gangrene [29].

### Diagnostic studies

- Absence or weak pulse distal to arterial anastomosis
- Decrease Doppler waveform in radial and ulnar arteries.
- Systolic pressure index- forearm systolic pressure divided by contralateral forearm pressure critical ischemia less than 0.4 [30].



**Figure 8:** Angiogram of steal complication from brachiocephalic fistula which confirmed by returning a distal arterial flow after clamping the fistula [31].

**Treatment**

**Low flow steal syndrome**

**Proximalization of Arterial Inflow (PAI)**

PAI involves ligation of the AV anastomosis and conversion of inflow to a more proximal level using a small-caliber (4 to 5 mm) prosthetic interposition [23].

**High flow steal syndrome**

- **Banding**

Stenosis of access near arterial anastomosis suturing or prosthetic wrap narrowing lumen 1cm with salvage to access [32].

- **Revision Using Distal Inflow (RUDI)**

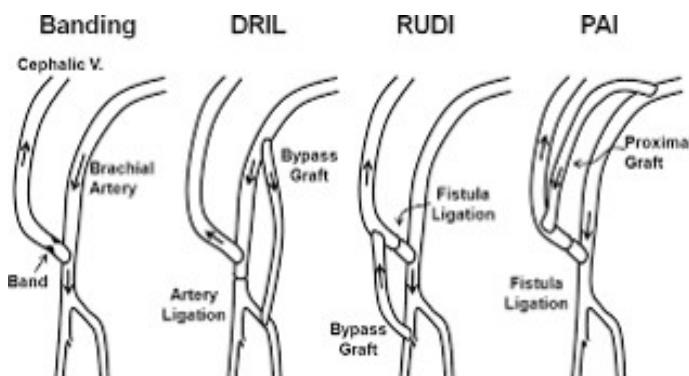
RUDI involves ligation of the fistula at the arterial anastomosis with reestablishment of flow from a more distal artery via bypass or translocation of a vein side branch.

This decreases flow through the access by reducing the diameter of the fistula and taking inflow from a smaller vessel [33].

- **Distal Revascularization–Interval Ligation (DRIL)**

DRIL entails the creation of a bypass originating proximal to the access anastomosis and terminating distal to it, with ligation of the artery distal to the anastomosis.

This prevents retrograde flow from the distal vessels and creates a low-resistance pathway for blood to reach the peripheral vascular bed [17].



**Figure 9:** Diagram demonstrate the different types of surgical approach to treat steal complication of A.V access [19].

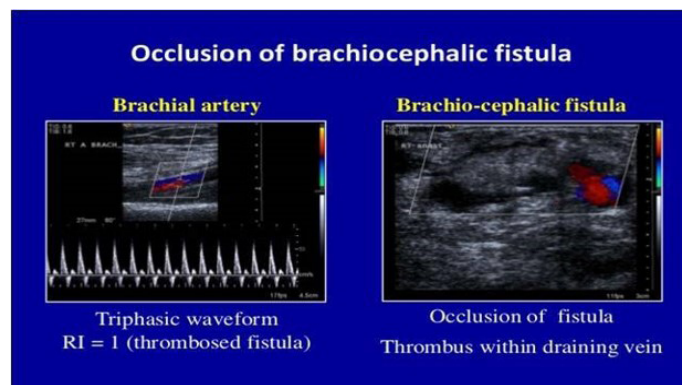
**Ischemic Polyneuropathy**

Most common in diabetic patients with severe forms of peripheral arterial disease, especially when the brachial artery is used for creation of vascular access. It is manifested by weak arms, in the immediate preoperative period, severe pain, and paresthesia. Neurological examination shows weakness in distal muscle groups in the area of sensory innervation by a defective median nerve [12].

**Thrombosis**

Platelets are activated by adhesion to the extracellular circulatory system and the turbulence in blood flow generated by the vascular access. Fibrinogen, which has an increased concentration in patients on chronic HD, activates platelets and increases further platelet deposition. Adherent platelets release Platelet-Derived Growth Factor (PDGF) to initiate intimal hyperplasia, thereby reducing blood flow [34].

The most common cause of vascular access failure is venous neo-intimal hyperplasia. This cause’s vascular stenosis, leading to fistula thrombosis. Neo-intimal hyperplasia is characterized by the proliferation of smooth muscle cells. The smooth muscle cell layer penetrates through the internal elastic lamina, migrates into the intima, and secretes matrix proliferous substances, such as collagen, elastin and proteoglycans [35].



**Figure 10:** Color duplex US denotes thrombosed brachiocephalic fistula US [36].

Endothelial vasodilator activity (nitric oxide, prostacyclin and bradykinin) is significantly reduced, while the synthesis of powerful vasoconstrictors (endothelin, angiotensin II and free oxygen radicals) is increased. Restenosis is one of the important pathophysiological events in the endothelium of blood vessels; it may occur after percutaneous transluminal methods of angioplasty [37].

AVGs are 3.8 times more likely to require a thrombectomy and 3 times more likely to require access intervention than AVF [38].

**Venous hypertension**

Due to central venous stenosis or occlusion or valvular incompetence [39].

**Presentation**

- Asymptomatic due to good collateral development
- Arm swelling and pain lead to cyanosis and ulceration
- Distended collateral in shoulder and chest [40]

### Grading of severity

Grade 0: None

Grade 1: Mild to minimal symptom discoloration minimal extremity swelling

Grade 2: Moderate---intermittent discomfort, sever swelling

Grade 3: Constant discomfort, hyperpigmentation, venous ulceration [41]

### Treatment

Management is controversial. Ligation is well tolerated and provides symptomatic relief but sacrifices a functional access and leaves the ipsilateral extremity unavailable for future access [42].

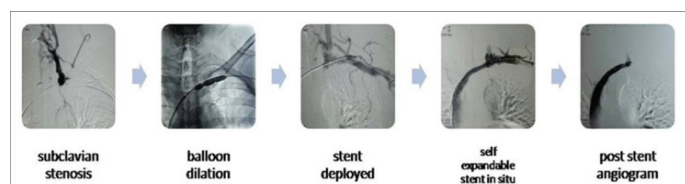
### Treatment of peripheral valve incompetence

Ligation of tributaries or embolization of tributary vein to access via endovascular [43].

### Treatment of central vein stenosis

#### Endovascular intervention

Angioplasty and stenting remain the first-line [44].



**Figure 11:** Angiogram of ballooning and stenting subclavian vein stenosis [45].

### Open Surgical Techniques

Surgical treatment has substantial morbidity and is reserved for patients untreatable with angioplasty/stenting [46].

#### Techniques include

Direct reconstruction, decompression, and bypass

- First option....Surgical repair with a spiral saphenous vein graft.
- In modern series.... prosthetic bypass, with outflow including right atrium, femoral vein or saphenous vein are commonly used [47].

### Recommendations

1. Preoperative US evaluation for the detailed vascular mapping was performed by assessing venous and arterial diameter able to maintain sufficient blood flow and fistula maturation [8].
2. Postoperative US in addition to physical examination can be used in detecting early clinical symptoms of AVF dysfunction in order to prevent and adequately treat potential complications as thrombus, stenosis and aneurysm [19].
3. The native AVF is the vascular access of choice for patients who require hemodialysis: it lasts longer and is associated with fewer complications than AVG [7].

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