2 Preoperative Evaluation: Physical Examination

Mukesh Kumar Sharma and Vandana Dua Niyyar

Introduction

> He who studies medicine without books sails an uncharted sea, but he who studies medicine without patients does not go to sea at all. – *William Osler*

Physical examination is a low-cost, quick, convenient, and a noninvasive invaluable tool that assists in diagnosis and evaluation of the patient and has been used since the advent of medicine. As nephrologists and interventionists, we are well aware that hemodialysis vascular access problems represent an exceedingly important part of the management of the end-stage renal disease patient. A thorough and detailed physical examination is an excellent, noninvasive, and accurate method for initial evaluation and helps guide our interventional procedures – not only those that we do but also those that we do not do. For general nephrologists and dialysis staff, a proper physical exam can provide useful insights in better screening, access monitoring, and early detection of access dysfunction so that a timely referral can be made for needed intervention to prolong the life of the dialysis access. For interventionists a good physical exam of an access provides valuable information for proper pre-procedure planning and can increase the success of planned interventions and in some cases may also help avoid needless interventions. Performed by a trained caregiver, physical exam is an accurate diagnostic tool for early detection of stenosis in a great majority of dysfunctional AVFs [1, 2].

General Examination

An abbreviated history and physical should be performed on every patient that presents for an interventional procedure, focusing not only on the presenting symptoms but also on allergies, comorbidities, and a review of systems. A medication history focusing on chronic systemic anticoagulation and pain medication should also be obtained, as adjustments may need to be made to the doses used in conscious sedation and the use of heparin or thrombolytics. A detailed history of any previous episode of contrast allergy, anaphylaxis, adverse drug reactions, response to sedation medications, and/or the need for reversal agents in the past should be obtained from the patient and family if possible. Access-focused history and exam should include information on previous accesses (surgical scars, old grafts in the limbs), evidence of central venous catheters (exit site scars on the chest wall and venotomy scars on the neck), evidence of central vein stenosis (i.e. swollen extremities), evidence of SVC stenosis (swollen extremities and face), and the presence of collaterals in chest wall (Fig. 2.1). In addition, the upper arms should be inspected for scars from the presence of PICC lines. The chest wall should be inspected for any port-a-caths (used for chemo infusions) and cardiac rhythm devices (as the wires associated with these devices are notorious for causing central vein stenosis).

Examination of Dialysis Access

The fundamental concept in an access examination is to detect early access dysfunction so that it can be timely corrected to promote maturation, prevent thrombosis, and thus prolong the life of the access. A thorough physical examination of the access itself is essential prior to performing an interventional procedure. Not only does it provide information with regard to the source of the problem but also aids in planning the interventional procedure and the direction of cannulation. Numerous studies have shown excellent

M. K. Sharma
Sierra Nevada Nephrology Consultants, University of Nevada Reno School of Medicine, Reno, NV, USA
e-mail: msharma@nevadakidney.com

V. D. Niyyar (✉)
Division of Nephrology, Emory University, Atlanta, GA, USA
e-mail: vniyyar@emory.edu

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Fig. 2.1 Central vein stenosis resulting in arm swelling and large collateral veins in the chest. Evidence of several tunneled catheter insertions is provided by several catheter exit site scars in the chest and Venotomy scars in the neck area

correlation of the accuracy of physical examination as compared to the gold standard (angiography) in both AVF and AVG [1, 3, 4]. Indeed, physical examination has shown to be equivalent to, if not superior to, normalized pressure ratios [5], ultrasound [2, 6], intra-access pressures [7], and even the gold standard, i.e., angiography [8], in detecting access dysfunction. In a comparison of the accuracy of physical examination performed by a trained nephrology fellow as compared to an experienced interventionist, the authors reported a strong correlation between their findings, concluding that physical examination of the dialysis vascular access is an important and easily taught skill that should be incorporated in a formal training curriculum [8, 9]. Latest KDOQI vascular access guidelines recommend regular physical exam as a monitoring process to detect flow dysfunction of the AVF [10].

This chapter details the general physical examination as well as intervention-specific scenarios for particular interventions.

Physical Examination Prior to Access Placement

The objective of doing a physical exam in each patient prior to access placement is to select the most ideal blood vessels that would reduce primary failure rate and maximize the chances of placement of an AV access that would eventually mature and can be used for dialysis. 80% of patients initiating HD in the USA in 2015 started HD through a catheter, a rate that has not changed much since 2005 [11]. Patients with advanced CKD and ESRD have several comorbidities and challenges that serve as barriers toward getting a mature AV Access. Frequent phlebotomies, peripherally inserted central catheters (PICC) lines [12], and a high prevalence of comorbid conditions including diabetes, obesity, and vascular disease [13] in this high-risk population may negatively impact the vasculature and contribute to early AVF dysfunction and primary failure to mature. In order to mitigate this complication, and select the right patient for the right kind of AV access, preoperative evaluation and physical exam for arteriovenous fistula (AVF) placement can, and must, be done. Latest KDOQI 2019 guidelines on vascular access recommend greater emphasis and training in preoperative clinical examination to assess patients and their vessels prior to placement of vascular access [10]. Simply put, the idea is to find an ideal vein that can be anastomosed to a good artery so that a decent AVF can be formed and can mature once it is created.

For preoperative purposes, the physical exam can be broken down into (a) evaluation of arterial system and (b) evaluation of veins.

(A) Arterial Evaluation – Allen Test

The right artery used for AV access creation should provide adequate inflow for access development without compromising the distal blood supply of the forearm and hand. Most patients prefer using their non-dominant arm for access placement, but the dominant arm should not be ruled out if it has optimal vessels.

Arterial exam can be done in three simple steps:

1. Documentation of bilaterally equal strong pulses. The brachial, radial, and ulnar pulses should be examined in both upper extremities, and their quality should be recorded, whether normal (2+), diminished (1+), or absent (0).
2. Differential blood pressure measurement: BP measurements should be taken in both arms; a difference of 20 mm Hg or greater in systolic blood pressure between the two arms is abnormal and should be recorded.
3. *The Allen test*: helps to confirm the patency of the palmar arch and thereby the collateral circulation to the hand. Normally the ulnar artery is able to support the arterial circulation to hand through palmar arch even in presence of decreased radial artery flow. This test should be performed prior to creation of any AVF, but particularly a forearm AVF to screen patients at high risk for developing steal syndrome. The patient is asked to make a fist, and pressure is applied over both the ulnar and the radial arteries to occlude them. Once the fist is opened, the hand should appear blanched or pale. Then, pressure is alternately released from both the arteries and the hand monitored for return to color. If the color returns rapidly on release of the individual artery, it suggests that the blood supply to the hand is sufficient (Fig. 2.2).

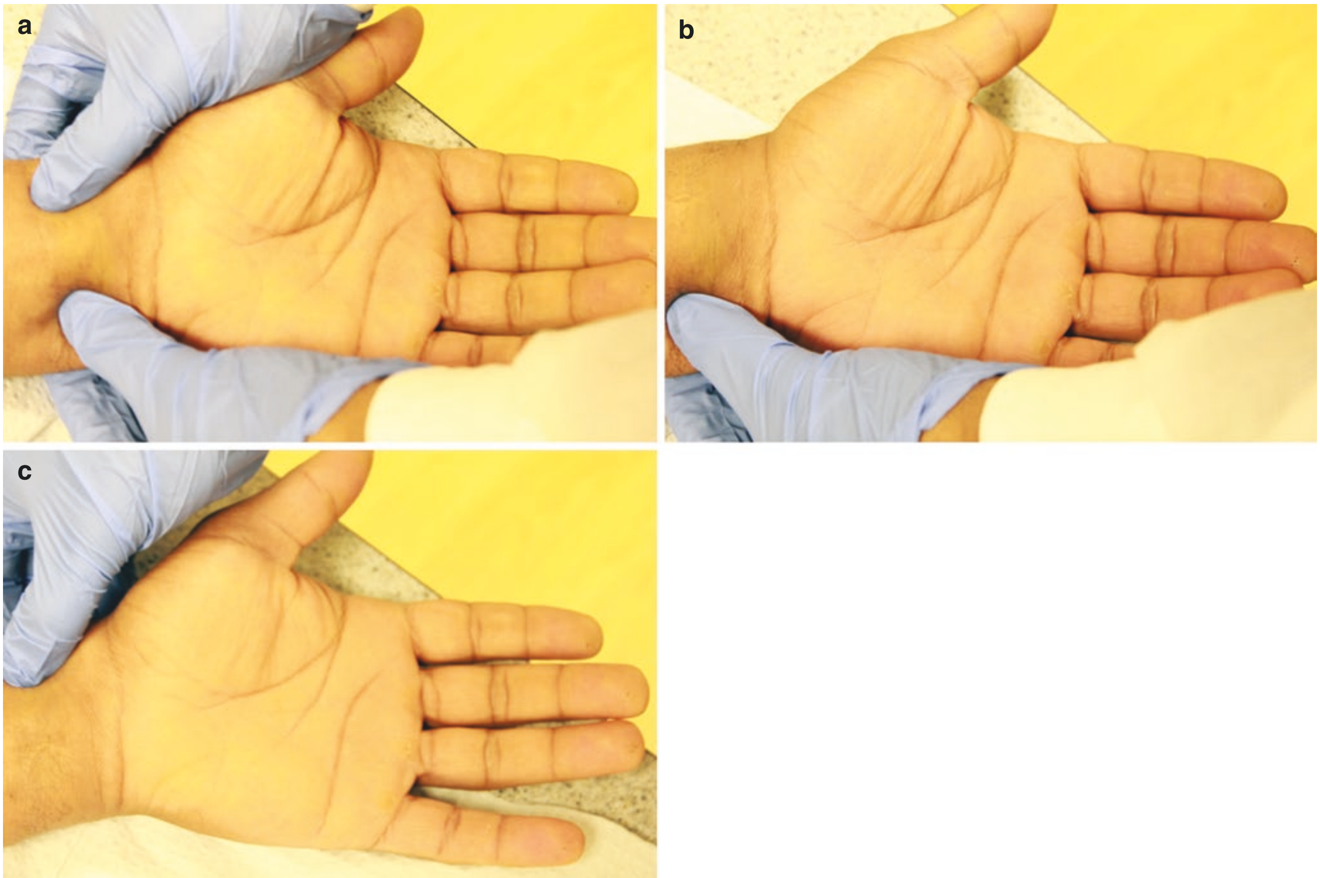

Fig. 2.2 The Allen test. The patient is asked to make a fist, and pressure is applied over both the ulnar and the radial arteries to occlude them (**a**). Once the fist is opened, the hand should appear blanched or pale. Then, pressure is alternately released from both the arteries and the hand monitored for return to color. If the color returns rapidly on release of the individual artery, it suggests that the blood supply to the hand is sufficient (**b** and **c**)

This test is called a *modified Allen test* by using a pulse oximeter probe on tip of a hand digit. Adequate manual occlusion of arteries is signaled by loss of pulse waveform. Return of pulse waveform as each artery is released signals patency of that artery. If either ulnar or radial artery has decreased patency, a wrist AVF should not be created.

(B) Evaluation of Veins

For the venous examination, a tourniquet is placed sequentially at the upper extremity, and the veins are visually inspected to determine the diameter, the distance of the vein from the skin surface, and the length of a straight venous segment suitable for cannulation [14]. This simple test, though valuable, is often inadequate when used alone – particularly in obese patients or those with a history of prior vascular access. In such cases, it may need to be supplemented with additional techniques, such as ultrasonography or venography [15]. In a cohort of 116 patients, the authors classified vein quality as good in patients in whom the cephalic vein was easily visualized, poor with hardly visible veins, and absent when no veins could be seen on physical examination. In patients with poor or absent veins, duplex sonography was performed, and venography was reserved for those patients who did not have adequate veins on both physical examination and ultrasound. Preoperatively, clinically visualized veins could be found in only 54 of 116 patients (46.5%), and poor or clinically absent veins were found in 62 patients (53.5%). Further, of these 62 patients, duplex sonography found adequate veins in 48 patients (77%), and only 14 patients (23%) required venography [15].

Physical Examination Prior to Interventional Procedures on Arteriovenous Fistulae and Early Fistula Failure

Even with an increasing use of preoperative vessel mapping as described above, AVF have a high rate (20–50%) of primary or early fistula failure (AVF that either do not adequately develop or fail within the first 3 months) that precludes their successful use for dialysis [16].

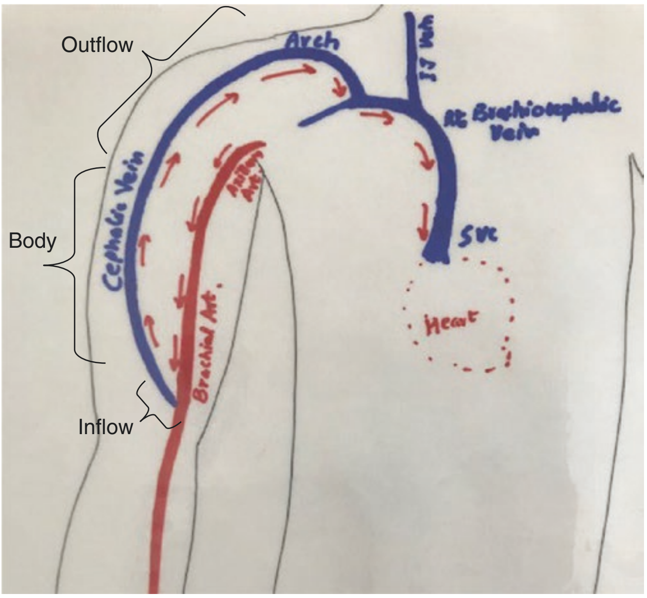

Fig. 2.3 Representation showing three segments of AVF: Inflow, Body, and Outflow

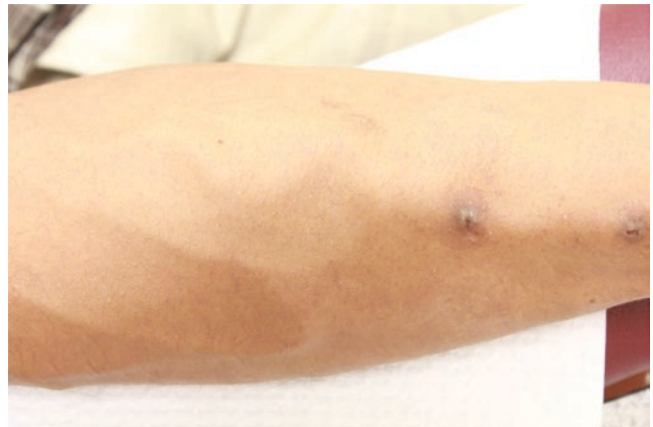

Fig. 2.4 Accessory veins in a forearm radiocephalic AVF. The main channel is well-developed and used for hemodialysis

Though there may be multiple reasons for early fistula failure, they are primarily due to "inflow" problems – arterial or juxta-anastomotic stenosis – or due to accessory veins that divert blood away from the main channel and prevent it from developing adequately. Physical exam of dialysis access can help monitor and detect early stenosis and has been shown to have a good correlation at detecting stenosis as compared to the gold standard tests such as angiography and Doppler ultrasound [17].

The vascular circuit of an access can be divided into three simple segments (inflow, body, and outflow) and needs to be conceptualized while examining any dialysis access (see Fig. 2.3). Inspection (look), palpation (feel the thrill), and auscultation (listen for bruit) are the three key components of physical exam of an access [10, 17, 18].

Inflow Problems

Augmentation Test

Arterial lesions are secondary to diseased, calcified arteries and, ideally, should have been evaluated preoperatively by vascular mapping. Juxta-anastomotic stenosis (a narrowing of the venous segment within 2 cm of the arterial anastomosis) is usually related to surgical trauma as this is the part of the vein that is manipulated to create the anastomosis. Inflow problems are easily diagnosed on physical examination by assessing the AVF for augmentation [18, 19]. On palpation of a normal AVF, there is a pulse at the arterial anastomosis and a soft compressible thrill throughout the AVF. On downstream occlusion (with a tourniquet or just manual pressure), the AVF augments or increases in size. However, in the presence of a juxta-anastomotic stenosis as the inflow into the access is limited by the stenosis, the augmentation is minimal or weak. Furthermore, the site of the stenosis can be detected by gradually moving proximally along the fistula, as the thrill weakens at the site of stenosis. Auscultation at the stenotic area reveals an auditory whistle suggestive of an obstruction.

Accessory Veins

In an ideal forearm AVF, there is one main channel (cephalic vein) which ultimately develops into a mature, usable AVF. However, the cephalic vein may have additional side branches (Fig. 2.4). Though this may be advantageous in that it allows several channels for the outflow and may even lead to the development of alternative sites for cannulation, in certain cases these accessory veins divert blood flow away from the main channel and may result in inadequate development of the AVF, resulting in early fistula failure.

Accessory veins are readily diagnosed by physical examination, as they are easily visible. Their significance can be ascertained by the effect of their occlusion on the main channel; if the AVF augments once the accessory vein is occluded, the accessory vein is significant, and ligation may be considered.

Late Fistula Failure

AVF that fail after 3 months of use are classified under late fistula failure and are commonly due to "outflow" problems as a result of venous stenosis. Other problems that AVF may present with include aneurysm formation, infection, high-output heart failure, and thrombosis. Each of these is individually discussed in detail below.

Outflow Venous Stenosis

Fistula Collapse or Arm Elevation Test

Venous stenosis in the outflow tract can be detected by a quick and simple bedside test called "collapse of the AVF" or "arm elevation test" [19]. If there is no stenosis in the outflow vein, simple elevation of the arm above the level of the heart will result in collapse of the AVF and a soft thrill on palpation (Fig. 2.5). In the presence of an outflow stenosis, because of the resistance to the blood flow back to the heart, the AVF does not collapse and becomes hyper-pulsatile. Auscultation reveals an audible high-pitched sound (whistle) with a change in the character of the thrill at the site of stenosis.

Aneurysm Formation

In patients with proximal (or outflow) stenosis, as a result of the increased pressure within the circuit, the AVF wall may weaken over time, leading to dilatation and the development of an aneurysm (Fig. 2.6). A true aneurysm is defined as dilatation of the outflow vein to more than three times the normal vessel diameter with a minimum aneurysm diameter of 2 cm

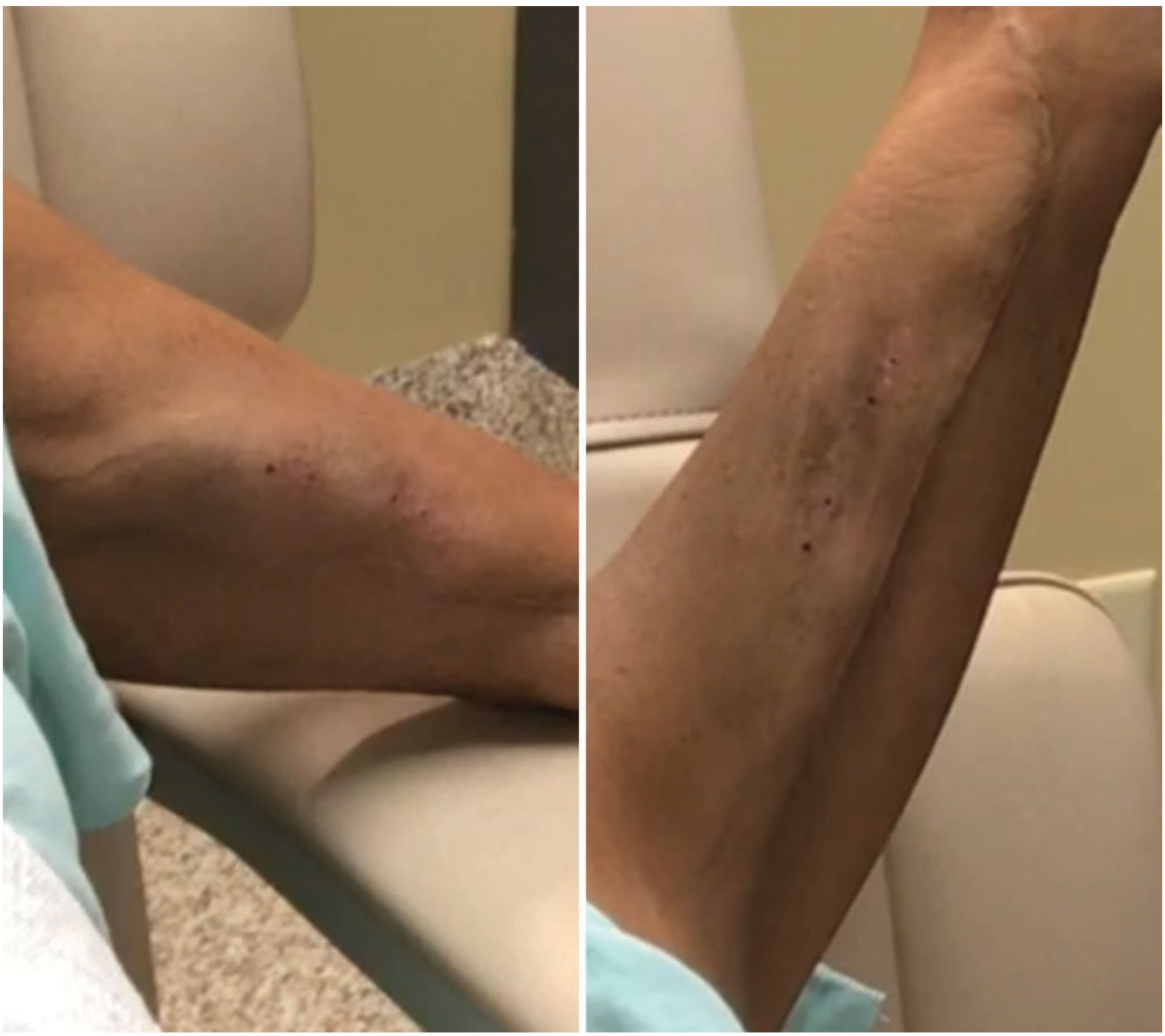

Fig. 2.5 Arm elevation and AVF collapse test. Left panel: AVF distended when arm at rest, AVF collapses when arm elevated above the heart level

Fig. 2.6 Aneurysmal AVF with associated skin changes

[20]. Aneurysms are more likely to develop distal to the stenosis, especially where the vessel wall has already been weakened by repetitive cannulations (one-site-itis). Aneurysms are not only cosmetically disfiguring, but their size and any associated skin changes should be progressively followed to determine if and when surgical intervention is needed. Aneurysm repair is indicated for symptomatic complications when aneurysms become large enough to impact the patient's quality of life or AVF use including skin changes such as thinning or erosion, pain, thrombosis, venous hypertension, or a shortened area for cannulation [20]. Impending rupture of the AVF is a relative emergency, and signs on physical examination include marked thinning, hypopigmentation, or ulceration of the skin overlying the fistula. The patient should be sent for emergent surgical repair with instructions on occluding the arterial inflow in the event of AVF rupture.

Some characteristics that can help determine if an urgent surgical intervention is required are (i) a rapidly enlarging aneurysm/pseudoaneurysm, (ii) overlying skin getting stretched out and as a result can be thin, shiny, and depigmented, (iii) signs of skin erosions such as ulcers or scabs on the overlying skin, and (iv) history suggestive of worsening/prolonged bleeding from the access. On the other hand, a relatively stable size of aneurysm, healthy overlying skin that can be pinched easily and has no skin erosion, and if AVF collapses easily on arm elevation, suggests that close watchful monitoring is appropriate and surgical intervention may not be required on urgent basis [10].

High-Output Heart Failure

The creation of an AVF leads to changes in hemodynamics and cardiac remodeling. In some upper arm AVF, especially brachiocephalic AVF, increased blood flow through the AVF (typically >2 l/min) predisposes patients with preexisting cardiac dysfunction to cardiac decompensation and the development of high-output heart failure [21].

These patients present with symptoms suggestive of worsening heart failure and shortness of breath and have a resting tachycardia on examination. Occlusion of the AVF results in a decrease in the pulse rate (Nicoladoni-Branham sign) and may add important clinical information regarding the hemodynamic significance of the AVF [22]. The management of these patients usually requires reduction or obliteration of the flow through the AVF, which results in symptomatic improvement [23–25].

Distal Ischemia

Hand ischemia in patients with an arteriovenous access is a serious complication, and a detailed history and physical examination helps to delineate the underlying etiology [26]. The key factors in examination are distal arterial pulses, skin temperature, gross sensation, and movement and should be compared to the contralateral side (Fig. 2.7). Patients with preexisting peripheral vascular disease, diabetes, smoking, and those with brachial artery AVF (as compared to radial artery AVF) are more predisposed to the development of ischemia [27]. In the classic "steal syndrome" or distal hypoperfusion ischemic syndrome (DHIS) [26], the patient presents with hand pain that worsens on dialysis, a cool hand with cyanotic discoloration, and decreased pulses. In more severe cases, evidence of ischemic changes in the skin, especially at the fingertips, may be present. A distal pulse that is weak on initial examination and strengthens on AVF occlusion is suggestive, though not pathognomonic, of arterial steal, as it suggests that the access is stealing too much blood away from the distal extremity. Differential diagnoses include (a) ischemic monomelic neuropathy that presents acutely with weakness of the muscles with prominent sensory loss from nerve damage due to vascular insufficiency and (b) carpal tunnel syndrome that presents with chronic hand weakness, numbness, and pain unrelated to dialysis. It is essential to identify the pathophysiology of the hand pain prior to the interventional procedure, particularly if the patient presents with a concomitant outflow stenosis, as an angioplasty to improve the blood flow through the access may inadvertently worsen the ischemic symptoms.

Thrombosed Access

When a patient presents with a thrombosed access, there is no palpable thrill or bruit on auscultation throughout the access, though a pulse may still be palpable at the arterial anastomosis. The number of days since the last full hemodialysis session should be noted and the patient placed on a monitor preoperatively to monitor for cardiac effects of hyperkalemia including bradycardia and EKG monitoring

Fig. 2.7 Left hand arterial insufficiency and hand ischemia due to left brachiocephalic AVF in an elderly female. Right panel shows both hands and more robust and preserved distal arterial supply to right hand

suggestive of prolonged P-R or Q-R-S intervals. Additionally, if the patient has a thrombosed "mega-fistula," it is likely that there is a large thrombus burden leading to a higher risk of symptomatic pulmonary embolism.

Physical Examination Prior to Interventional Procedures on Arteriovenous Grafts

Determining the Direction of Flow

The access circuit begins and ends in the heart; and the direction of flow is from the feeding artery to the draining vein. However, in instances with unusual configurations and loop arteriovenous grafts, it is essential to determine the configuration prior to cannulation to avoid recirculation. At the bedside, the AVG is occluded at the apex of the loop, and both sides are palpated (Fig. 2.8). The arterial (inflow) limb of the graft will have an augmented pulse as the blood tries to force past the occlusion, while the venous (outflow) limb of the graft will have a diminished or absent pulse.

Venous Stenosis

Though venous stenosis in an AVG, similar to an AVF, is secondary to outflow stenosis, the underlying pathophysiology differs in that it is a result of the development of neointimal hyperplasia at the vein-graft anastomosis (VGA) [28]. The VGA is also the most common site of stenosis in a graft circuit. The graft and draining veins are examined to determine the character of the pulse, the location and intensity of thrills, and the duration and pitch of the bruit. The physical examination reflects the increase in pressure within the access circuit consequent to the downstream stenosis, and the AVG is pulsatile throughout, not just at the arterial anastomosis. The normal character of the soft bruit changes, and there is a high-pitched, harsh bruit at the site of maximum turbulence.

Fig. 2.8 To determine direction of flow, the AVG is occluded at the apex of the loop, and both sides are palpated. The arterial (inflow) limb of the graft will have an augmented pulse as the blood tries to force past the occlusion, while the venous (outflow) limb of the graft will have a diminished or absent pulse

Pseudoaneurysms

AVG-associated pseudoaneurysms differ from AVF-associated true aneurysms, as they are composed of skin and fibrous connective tissue and are secondary to a combination of outflow stenosis causing an increase in pressure within the access, with repetitive cannulation at the same sites leading to dilatation at the site of the resultant graft defect. The presence of a pseudoaneurysm necessitates an evaluation for venous stenosis (Fig. 2.9). The overlying skin should be closely monitored for thinning, hypopigmentation, scarring, ulceration, or spontaneous bleeding, as it may rupture leading to massive hemorrhage.

If the diameter of the pseudoaneurysm is greater than twice the diameter of the graft, the patient should be referred for surgical revision [29]. Placement of a stent graft should be avoided in the cannulation area due to concerns for infection and the risk of protrusion of the stent through the skin [30].

Infections

Infection of an AVG is a serious complication, and it is essential to differentiate a reactive inflammation (secondary to thrombosis or postoperative) from a true graft infection. Immediately postoperatively, an inflammatory dermal reaction localized to the graft may be seen; pain and the associated swelling may make it seem similar to a superficial or deep graft infection. Superficial graft infections are generally related to a cannulation site and present as a localized area of cellulitis. On physical examination, there is minimal or no inflammation, swelling, or pain. Deep graft infections are usually at the site of graft surgery or cannulation sites and characterized by the classic signs of inflammation including erythema, warmth, and a fluctuant swelling extending into the surrounding tissues. It is often painful, and management involves partial or total graft excision [31] (Fig. 2.10).

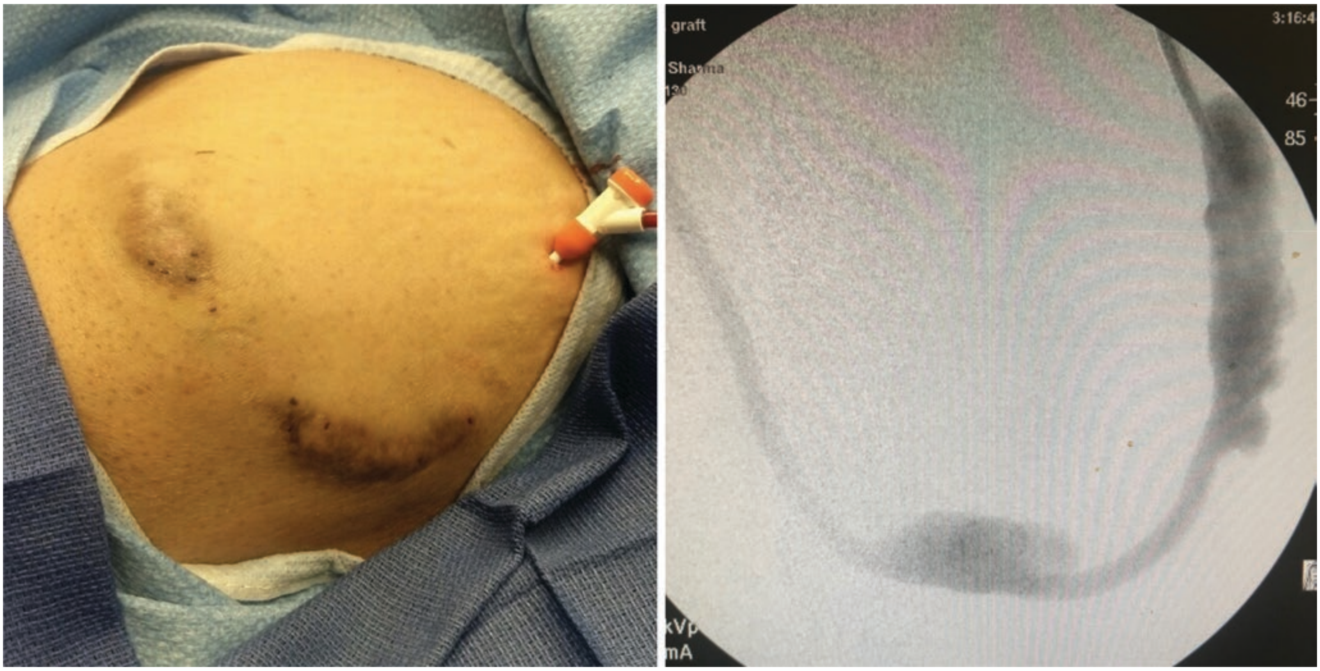

Fig. 2.9 Thigh graft with two large pseudoaneurysms developed mainly due to repeated cannulations in the same area (one-site-itis). Accompanying angiogram shows how large the pseudo aneurysms are relative to the graft size

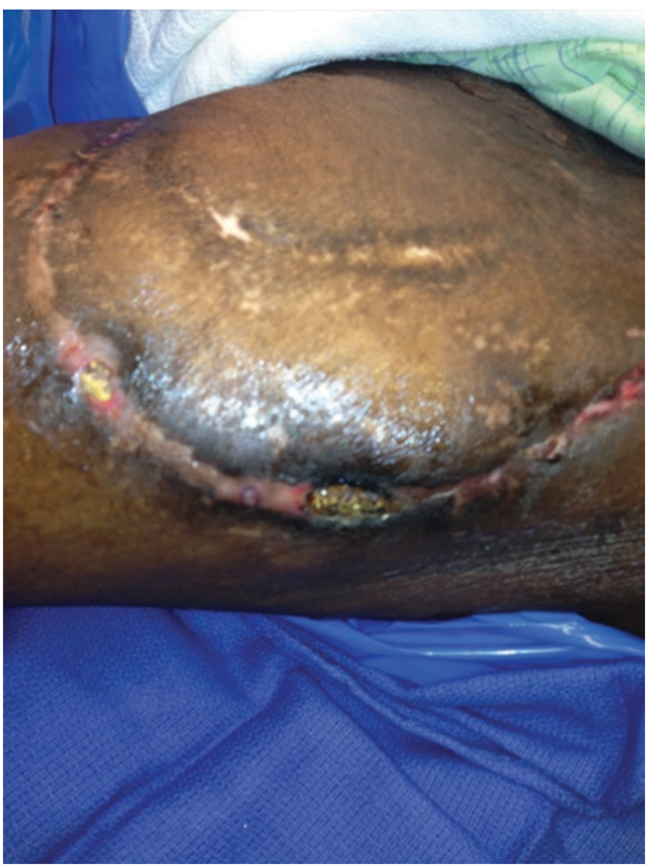

Fig. 2.10 Thigh graft infection requiring complete excision of the graft. Several areas of the graft are seen exposed and overlying skin all along the loop graft appears inflamed and thinned out. Also seen is the previous failed thigh loop graft that is no longer in use

Thrombosed Access

On examination of a thrombosed AVG, there is no palpable thrill or bruit on auscultation throughout the graft, though a pulse may still be palpable at the arterial anastomosis. There may be a reactive superficial cellulitis in response to the underlying thrombus, which must be differentiated from a true graft infection as detailed above, prior to attempting an endovascular procedure. The mean clot volume in a thrombosed graft has been shown to be much lower than expected (3 cm^3) [32], and by inference, the risk of symptomatic pulmonary emboli may be less than that with mega-fistulas unless there are associated pseudoaneurysms. Physical exam of the AV access should be done each time prior to cannulation, and all caregivers including the patient and family can be trained to pick up subtle changes to timely alert and refer for intervention so that access thrombosis can be prevented [33].

Physical Examination Prior to Interventional Procedures on Central Venous Catheters

Central Venous Stenosis

Central venous stenosis may present with swelling of the arm, neck, and/or face based on the site of stenosis. If the stenosis is in the subclavian vein, the patient presents with unilateral arm swelling (Fig. 2.1); the stenosis of brachiocephalic (or innominate) vein can cause swelling of the ipsilateral arm, neck, and face, while a stenosis of the superior vena cava presents with bilateral swelling of the arms, face, and neck (SVC syndrome). A detailed history of previous central venous catheters including scars on the chest wall (Fig. 2.11), PICC lines, and cardiac rhythm devices and the presence of collaterals (Figs. 2.1 and 2.11) should be performed and documented. Other risk factors for central venous stenosis include the caliber, site (subclavian > internal jugular), and duration of the catheter [34]. It is important to realize that central venous lesions may be asymptomatic, and not all cases are associated with a previous history of a central venous catheter (Fig. 2.12).

Infections

Management of tunneled dialysis catheters infections differs based on their site of involvement. These infections can be classified as exit site infections, tunnel infections, and catheter-related bacteremia (CRB). An exit site infection is restricted to the exit site and is easily recognized on physical examination by redness, crusting, and exudate. An exit site infection is a localized infection and should be treated with topical antibiotics [29]. A tunnel infection is defined as infection within the catheter tunnel – the part of the catheter from the cuff to the exit site. The patient presents with warmth, redness, swelling, and exquisite tenderness over the catheter tunnel, and occasionally an exudate may be expressed from the tunnel. Appropriate treatment consists of removal of the catheter and systemic antibiotics based on culture results. If the patient needs dialysis prior to resolution of the infection, a catheter should be placed at an alternative site. Catheter-related bacteremia reflects bloodstream infection, and these patients present with systemic symptoms including fever, chills, and a positive blood culture. There are no other clearly visible signs on physical examination, though a CRB may present with a concomitant exit site or tunnel infection. The management is based on the infecting organism, the need for dialysis, and the hemodynamic stability of the patient [35].

Fig. 2.11 Previous central venous catheter scars on the chest wall and the presence of collaterals

Fig. 2.12 Swollen arm and hand due to outflow vein stenosis in a forearm radio-cephalic AVF

Conclusions

Even with the advent of elaborate and expensive technology, physical examination is far from obsolete. An inexpensive, quick, and thorough physical examination performed at the bedside provides essential clues to the management of vascular access in hemodialysis patients. It is an invaluable, noninvasive, and an easily teachable skill in the nephrologists and interventionists armamentarium and can be easily taught to dialysis nurses, technicians, and care providers including patients themselves. Regular physical exam of the access should be utilized more widely and frequently.

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