23 Arterial Stenosis Affecting Arteriovenous Fistulae and Grafts in Hemodialysis Patients: Approach to Diagnosis and Management

Diego A. Covarrubias, Chieh Suai Tan, Shaker S. Qaqish, Karthik Ramani, and Steven Wu

Introduction

Adequate arterial inflow is an essential requirement of a successfully functioning arteriovenous (AV) access for hemodialysis (HD). Patients with end-stage renal disease (ESRD) on HD have a high incidence of peripheral artery disease (PAD) and vascular derangements in general. The arteries utilized for AV access creation are subject to similar pathologic processes as those of the lower extremities in this population, which can lead to impaired access function or failure. Arterial disease, though increasingly recognized as a potential factor in AV access dysfunction, continues to be a relatively under-appreciated and thus under-explored cause of the said dysfunction. This chapter will provide an overview of the approach to the patient with suspected arterial stenosis leading to AV access dysfunction.

D. A. Covarrubias (✉)
Interventional Radiology, Kaiser Permanente West Los Angeles Medical Center, Los Angeles, CA, USA
e-mail: diego.a.covarrubias@kp.org

C. S. Tan
Department of Renal Medicine, Singapore General Hospital, Singapore, Singapore
e-mail: tan.chieh.suai@singhealth.com.sg

S. S. Qaqish
Interventional Nephrology, Kidney & Pancreas Transplant, Advanced Vascular Care, Brooklyn, NY, USA
e-mail: ssq@drgelbfish.com

K. Ramani
Interventional Nephrology, University of Michigan, Ann Arbor, MI, USA
e-mail: ramanik@med.umich.edu

S. Wu
Interventional Nephrology, Department of Medicine, Massachusetts General Hospital, Harvard Medical School, Boston, MA, USA
e-mail: SWU1@mgh.harvard.edu

Definition, Epidemiology, and Pathophysiology

Definition of Arterial Stenosis

The precise definition of arterial stenosis in the setting of HD AV access is somewhat arbitrary. An acceptable working definition is an arterial stenosis of 50% or greater decrease in luminal diameter as compared with adjacent normal caliber artery occurring in the arterial inflow to the AV access anywhere from the anastomosis to the ascending aorta. This corresponds to the threshold degree of stenosis that typically triggers the need for intervention in the venous portion of the AV access [1]. This will be the definition used for the purposes of this chapter. Some authors specifically choose to exclude the juxta-anastomotic region in their definition of arterial stenosis; however, lesions in specific locations will be addressed later in the discussion.

Epidemiology of Arterial Stenoses

Historically, arterial inflow stenoses were considered to be a rare cause of dysfunctional AV access, especially when compared to lesions of the venous outflow. Early estimates cited occurrence of arterial stenoses in 0–4% of patients [2], while current literature acknowledges that arterial or inflow stenoses are a major cause of AV access dysfunction, with an incidence of up to 40% [3]. The juxta-anastomotic region accounts for the majority of lesions, involved in up to 50% of arterial stenoses in the early phase of access creation and an even higher proportion of lesions in mature fistulas [4]. Up to 30% of lesions involve the more proximal feeding arteries, those leading up to the junta-anastomotic region. A higher incidence of inflow stenoses is seen in forearm AV access compared to the upper arm location [5]. Also, a higher incidence of these lesions is seen in fistulas than grafts [6]. Most commonly, non-anastomotic stenoses are seen in the subclavian artery, followed by the radial artery [7]. The likelihood

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of arterial lesions increases with increasing age [8]. Venous stenoses coexist with arterial lesions up to 54% of the time in patients with fistulas and up to as high as 100% of the time in patients with grafts [9].

Pathophysiology of Arterial Stenoses

The pathogenesis of arterial inflow stenosis is complex and multifactorial in etiology. In the HD population, a proportion of patients will inevitably have some degree of underlying arterial disease present prior to surgical creation of AV access. The high-flow state the vessels endure under regular hemodialysis is also likely a contributory causal factor, in combination with inflammatory, genetic, and hemodynamic responses leading to eventual neointimal hyperplasia and vascular remodeling [10, 11]. These lesions, along with calcified and non-calcified atherosclerotic plaques, are the precursors to arterial stenoses [12]. Aside from the high-flow state of HD, continuous inflammation caused by repeated needle access, indwelling graft material, the underlying uremic milieu, and other factors lead to a host of responses mediated by activation of cytokines, chemokines, leukotrienes, and other pathways that contribute to both initiation and accelerated progression of these lesions [12–14]. As these lesions develop and advance in severity, they lead to luminal narrowing and eventually stenosis (Table 23.1 Pathogenesis).

Initial Evaluation

The presence of limb ischemia during hemodialysis may prompt a search for a specific cause. While the differential diagnosis may be broad, an arterial lesion should be considered and ruled out as this may represent a curable etiology.

History

Evaluation should begin with the taking of a thorough history. This would include questioning regarding the occurrence of relevant symptoms such as claudication, the presence of cold hands or feet, and rest pain. The relationship of these symptoms to hemodialysis sessions should also be determined, with careful recording of number of occurrences, nature/character of symptoms, as well as duration and whether or not the limb affected contains the AV access. Patients should also be questioned concerning a history of previous surgery, trauma, or prior failed AV access. The goal of history taking is to attempt to elucidate a specific cause of the symptoms in question. Admittedly, in the setting of an arterial stenosis as the causal factor, the history is limited in contributing to actually arriving at the diagnosis.

Table 23.1 Factors involved in pathogenesis of AV access arterial stenosis

1. Genetic
Predisposition to neointimal hyperplasia, hypercoagulable state, atherosclerosis/PAD
2. Inflammatory
Repeated needle cannulation, surgery/angioplasty, uremic milieu, graft material
3. Hemodynamic
Small/noncompliant vessels, turbulent flow, general high-flow state of HD

Physical Examination

Physical examination in combination with a detailed history will increase diagnostic confidence. The physical exam should obviously be focused on the area of symptomatology. In the hemodialysis patient, this is most commonly in the limb containing the AV access. Palpation for thrill and tension is the first step in evaluating the AV access. However, abnormality in flow through the access on palpation is a nonspecific finding. Other basic initial maneuvers involve evaluation of the radial and ulnar blood supply as well as comparison of bilateral blood pressures. Allen's test can be utilized to evaluate the adequacy of the dual blood supply to the hand. Blood pressures in the extremity containing the AV access typically are 10–20 mmHg higher than in the contralateral extremity. If the blood pressure in the access extremity is lower than that in the contralateral extremity, this suggests the presence of arterial stenosis. Additional assessment of the extremity for stigmata of vascular compromise should also be undertaken. The presence of pain, sensory deficits, skin discoloration, and ulceration should be noted. If hand pain is present and relieved by occlusion of the AV access, distal hypoperfusion ischemic syndrome (DHIS) may be considered. This entity is commonly due to arterial stenosis and is specifically addressed in a separate chapter on hand pain. Additionally, loss of hair or nail bed changes should be sought. The physical examination may need to be repeated during a hemodialysis session, as the symptoms may only occur at such times.

Hemodynamic Parameters of Hemodialysis Vascular Access

Problems during HD are often the first manifestation of access dysfunction. Measurement of certain hemodynamic parameters of hemodialysis vascular access is an important component of AV access maintenance. Recent studies have found that when measurement of access blood flow (Qa) is less than 650 ml/min, this represents a relatively sensitive and specific sign of inflow stenosis [15, 16]. A full discussion of hemodialysis parameters is beyond the scope of this chapter.

The Importance of Prior Imaging Studies

In addition to history and physical exam, a thorough initial evaluation should include a review of pertinent prior imaging studies. AV access maintenance typically requires regular interventions to promote and achieve the patency rates necessary for regular dialysis, and the vast majority of these patients will have prior imaging examinations available [17]. The widespread acceptance of electronic medical records and picture archiving and communications systems (PACS) allows for a wealth of patient information to remain readily available to the physician/interventionalist. This information should be maximally utilized. A hemodialysis patient with symptomatology and history and physical exam findings suggestive of the presence of arterial stenosis may have a prior imaging study on file that could provide a clue as to the etiology. Such possible findings may include the presence of either central or peripheral vascular lesions or abnormalities. For example, review of a prior contrast-enhanced chest computed tomography (CT) examination obtained for non-HD-related issues provides a nearly complete map of the central arterial circulation and is invaluable in excluding a potential issue in this region. If prior imaging studies are not available or unhelpful, dedicated imaging of the central vasculature supplying the AV access may be advisable as this may facilitate a targeted intervention/procedure.

Diagnosis Requires a High Index of Suspicion

The signs and symptoms of arterial stenosis are usually nonspecific, rendering diagnosis by history and physical exam difficult. The challenge is compounded by the fact that commonly arterial and venous outflow lesions coexist. A high index of suspicion is necessary to pursue a diagnosis of arterial inflow stenosis. After successful and complete treatment of the venous disease, persistence of clinical features of inadequate arterial inflow or observation of sluggish flow on post-angioplasty angiogram warrants further investigation of the arterial tree. Clinical assessment can raise the index of suspicion for the presence of arterial stenosis, but the mainstay of diagnosis is via imaging.

Preventative Measures

Finally, preventative measures undertaken when planning placement of the AV access will ensure adequate future function. Ideally, the entire arterial tree supplying the intended site of AV access should be thoroughly evaluated prior to surgical creation. An arterial stenosis involving the inflow of the planned AV access may represent a subclinical preexisting condition which is only unmasked following surgical placement of a low vascular resistance AV access. Arterial lesions like these are extremely important to recognize because they can lead to poor AV access maturation and function as well as being the direct cause of symptoms such as hand ischemia. Subclinical arterial lesions likely contributed to the historically low rate of primary patency of AV access of approximately 50%, and increased awareness of the presence of such lesions as well as their discovery prior to surgery has notably improved patency [18]. Again, it is imperative to evaluate the entire arterial inflow prior to surgical creation of an AV access in order to decrease the probability of clinically significant issues involving the arterial side of the access arising in the future. Discovery of a significant arterial stenosis or lesion during pre-surgical work-up does not preclude placement of AV access, as many of these lesions can be successfully treated using endovascular techniques, such as percutaneous transluminal angioplasty (PTA) and/or stenting (Table 23.2 Evaluation).

Differential Diagnosis

The differential diagnosis of AV access dysfunction includes lesions of both the venous outflow and arterial inflow, as well as the access itself. When evaluating hemodialysis AV access problems, the practitioner should visualize the access as a portion of a circuit, which includes the heart, arterial inflow,

Table 23.2 Evaluation of patients with suspected arterial stenosis affecting an AV access

1. History	
	Inquire regarding claudication, "cold" hands, rest pain, relationship of symptoms to HD, previous surgery, trauma, or failed AV access
2. Physical exam	
	Palpate for thrill and tension
	Comparison of bilateral blood pressures (AV access extremity typically 10–20 mmHg higher)
	Search for stigmata of vascular compromise: skin discoloration, ulceration, loss of hair, nail bed changes
3. Assess hemodynamic parameters during hemodialysis	
4. Review prior imaging studies	
5. Obtain diagnostic studies	

AV access, and venous outflow. The circuit model allows for a systematic approach to potential clinical issues that may arise with an AV access. Each component of the circuit should be carefully evaluated, which will ensure a thorough assessment. For example, once other causes such as venous outflow obstruction, heart failure, and thrombosis are excluded, logically, the arterial inflow must be the culprit. Perhaps the major challenge in diagnosing and treating arterial stenoses lies in the lack of a standardized algorithmic approach to evaluation. Whenever a patient presents with a problematic AV access, the concept of the vascular circuit should be kept in mind, as rendered treatments may be insufficient if only one portion of the circuit is addressed. A highly specific and sensitive sign of arterial stenosis is when poor blood flow persists after adequate treatment of the venous outflow [9].

Diagnostic Studies

Overview

Assessment of the arterial tree in patients with problematic AV access can be performed with various modalities. The modalities differ in accuracy, effectiveness, and specific advantages and disadvantages. Noninvasive studies may provide an accurate diagnosis; however, treatment will typically require either endovascular intervention or surgery. Conventional angiography in the form of a fistulogram or graftogram is an acceptable first option for evaluation of dysfunctional AV access as it provides both a diagnosis and the potential to render treatment simultaneously. Again, given the typical comorbidities associated with the HD population, these patients will likely have undergone numerous prior noninvasive/diagnostic imaging examinations for evaluation of other conditions [19]. The value of this information cannot be stressed enough, and a prudent practice prior to pursuing further imaging is a thorough review of available previous studies.

Noninvasive Studies

Noninvasive modalities include ultrasonography (US); computed tomography (CT), including CT angiography; and magnetic resonance imaging (MR), including MR angiography.

Ultrasound

Ultrasound is a widely available, low-cost imaging modality uniquely suited to examination of vascular structures. The superficial location of HD AV access facilitates sonographic visualization. Sonography has the ability to quantify flow velocity and direction in real time and can depict morphologic abnormalities such as stenoses or thrombus [20]. US is ideally suited to preoperative evaluation of arteries and veins as well as monitoring of AV access maturation and potential dysfunction. Aside from diagnostic uses, US has an increasing practical role in preservation of AV access in the HD population as it can be used to guide safe cannulation of difficult to cannulate access sites, a practice that has become more common due to rising obesity rates [21]. Other advantages include the lack of ionizing radiation and the fact that intravascular contrast material can be avoided. Disadvantages of ultrasound include a limited field of view, an inability to evaluate the central vasculature, and significant dependence on the skill of the operator.

CT

CT is a mainstay of diagnostic imaging and clinical problem-solving applicable in a multitude of scenarios, including evaluation of HD AV access. CT is a widely available, cost-effective, and efficient means of evaluating the entire vascular circuit, from the left ventricle to the right atrium, providing extensive data sets with excellent spatial resolution [22]. CT angiography is a rapid, well-tolerated exam that can facilitate planning of potential interventions. It is superior to DSA for evaluation of both the central arterial and venous structures, particularly in evaluation of suspected cases of central/feeding artery derangement or extrinsic compression causing AV access compromise (Fig. 23.1). Other advantages include the ability to post-process acquired data, for example, creation of three-dimensional reconstructions which can be useful in surgical planning and educational and research purposes. CT also technically does not depend on the operator for high-quality images. The major disadvantages of CT include the use of ionizing radiation and intravenous contrast material. Newer low-dose CT algorithms have dramatically lessened patient radiation exposure while maintaining excellent image quality, somewhat mitigating this concern [23, 24]. Use of IV contrast material does not pose a significant clinical issue in patients on active HD. Often, however, AV access is created prior to HD initiation. In these pre-HD patients, there is potential for accelerating renal function decline due to exposure to contrast agents.

MR

MR is an advanced, noninvasive imaging modality offering advantages similar to CT in that it has the ability to depict the entire AV access circuit, particularly the central vasculature (Fig. 23.2). Distinct advantages when compared to CT include lack of ionizing radiation and available MRI sequences performed without intravenous contrast. The caveat, however, is that time of flight (TOF) and other non-contrast techniques are not as accurate as their contrast-

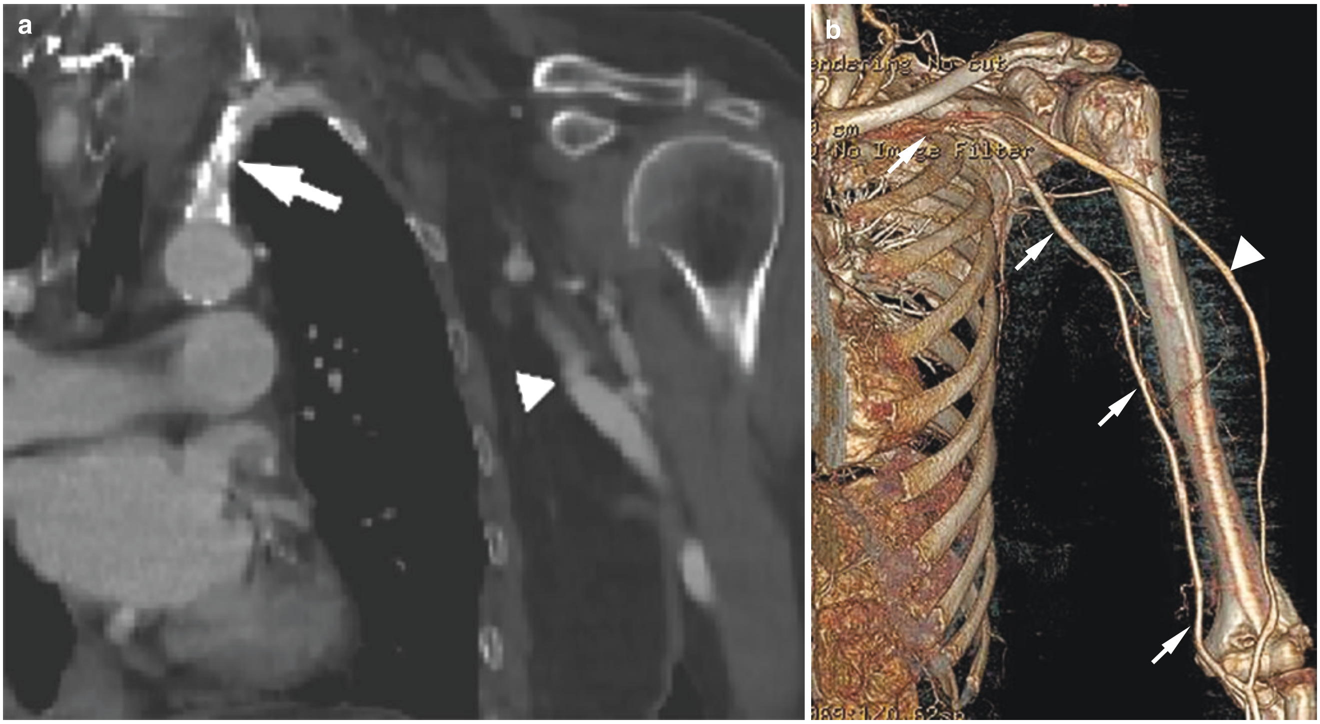

Fig. 23.1 Coronal image from a CT angiogram demonstrates atherosclerotic disease of the origin and proximal left subclavian artery (arrow) as well as depiction of more distal vasculature (arrowhead) in the left axillary region (**a**). 3D reconstruction from a CT angiogram performed for evaluation of suspected feeding artery stenosis depicting the left subclavian, axillary, and brachial arteries, which demonstrate no focal stenosis (arrows). Note the cephalic vein (arrowhead) filled in the arterial phase as the patient has an HD access in the distal upper extremity (**b**)

Fig. 23.2 Sagittal T2-weighted image from a non-contrast MRI depicts the normal aorta and origin of the left subclavian artery (arrow) in detail

enhanced counterparts and diagnostic confidence is potentially decreased by multiple artifacts, including those related to motion, graft material, and indwelling stents. MR venography (MRV) is a useful non-contrast technique that can be used to effectively evaluate venous structures in the pre-dialysis population prior to AV access creation [25]. Emerging MR techniques offer the promise of noninvasive evaluation of fluid dynamics; however, these are not currently widely available [26]. Contrast-enhanced MR angiography is an excellent study for evaluation of vascular structures. Unfortunately, the recognition of the association of nephrogenic systemic fibrosis (NSF) with poor clearance of gadolinium has limited the use of contrast-enhanced MR in the HD population [27]. Other disadvantages of MR include increased relative cost and longer image acquisition times, which may not be well tolerated by patients. Additionally, many HD patients have comorbid conditions that may preclude exposure to a magnetic field, such as an indwelling pacemaker. Patients with vascular stents pose a significant problem for evaluation with MR as the stents will create artifacts limiting evaluation of patency and adjacent vascular segments. Finally, bore sizes of MR units limit availability to obese patients.

Conventional Angiography

Conventional angiography is the gold standard method for evaluation of AV access dysfunction. It is highly accurate and can be used to evaluate the entire access circuit. A major advantage of angiography is that it allows for concurrent diagnosis and treatment, via endovascular techniques such as PTA and/or stenting (Fig. 23.3). Technological advancements in angiographic equipment now allow for acquisition of targeted cone beam CT images during interventional procedures, adding 3D data sets that may be a useful adjunct to conventional 2D angiogram images [28]. Disadvantages include the invasive nature of the procedure, use of iodinated contrast and ionizing radiation, relative cost, need for patient sedation and monitoring, and the potential occurrence of associated complications. Complications of conventional angiography include bleeding, infection, vascular injury, and contrast-associated issues such as potential anaphylaxis. Major complications, though rare, do occur, and patients may require emergent surgery.

Common interventional practice is to use the fistula or graft itself as the point of access for diagnosis or treatment (fistulogram/graftogram). This approach facilitates assessment of the venous outflow and anastomosis and allows for relatively simple and straightforward treatment of lesions on the venous side of the AV access circuit. Complete evaluation of the arterial inflow then requires crossing the anastomosis and placing a diagnostic catheter centrally, which is considered safer than direct arterial puncture in the upper extremity [29]. Noninvasive imaging studies may allow for detection of central lesions prior to fistulogram/graftogram. Armed with this knowledge, the operator could then consider a different approach to assist in treatment if necessary, such as the common femoral artery route (Table 23.3 Diagnostic studies).

Classification of Arterial Lesions

Overview

Arterial stenoses can be classified according to location and type. Locations include central, feeding, juxta-anastomotic, and distal arteries. These lesions can be due to intrinsic vascular factors such as underlying atherosclerosis or due to external factors such as compression by adjacent anatomic structures. The degree of stenosis can be described as mild, moderate, or severe. A severe stenosis is usually hemody-

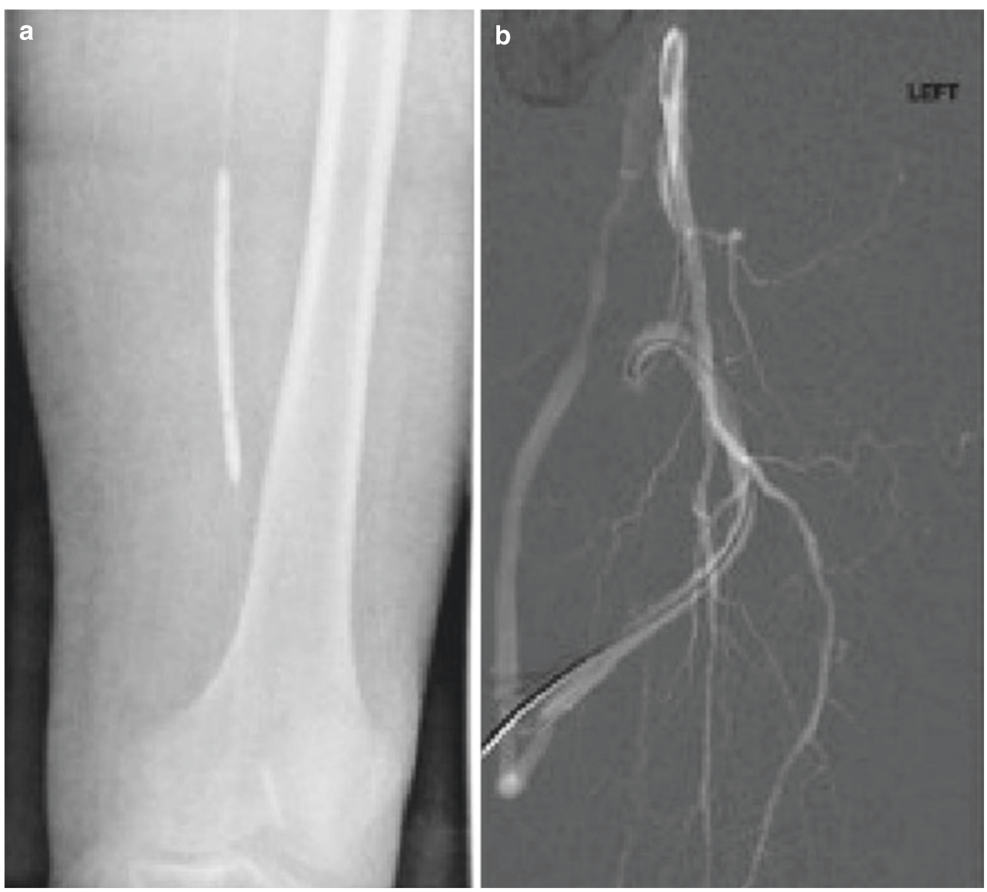

Fig. 23.3 Fluoroscopic image shows an angioplasty balloon inflated in the left superficial femoral artery (**a**). This was the feeding artery of a lower extremity AV access, which had occluded but was successfully recanalized (**b**)

Table 23.3 Diagnostic studies: advantages and disadvantages

1. Noninvasive:
(a) Ultrasound
Pro: widely available, low cost, ability to quantify flow velocity and direction in real time, can depict stenoses or thrombus, can be used to guide cannulation
Con: Inability to evaluate central vasculature, highly operator dependent
(b) CT
Pro: fast, evaluate entire arterial tree/venous outflow, excellent spatial resolution, post-processing, widely available, no operator dependence for high-quality images
Con: ionizing radiation, intravenous contrast material
(c) MRI
Pro: similar advantages to CT with additional lack of ionizing radiation
Con: longer image acquisition times, artifacts of non-contrast sequences, NSF, pacemakers and stents contraindicated, relative cost
2. Invasive:
(a) Conventional angiography
Pro: gold standard method for evaluation of AV access, highly accurate, evaluate entire access circuit, concurrent diagnosis and treatment (PTA/stent), cone beam CT
Con: iodinated contrast, ionizing radiation, relative cost, need for sedation/anesthesia, potential complications

namically significant. The significance of mild to moderate stenoses is generally not so easily qualifiable, with such lesions not necessarily associated with a hemodynamic abnormality. In the non-dialysis population, clinically insignificant mild to moderate stenoses may be the norm [30]. In HD patients, even a mild arterial stenosis can be problematic if it limits the inflow to the AV access or causes limb ischemia. As mentioned previously, given the high rate of conjunction of venous stenoses in AV access dysfunction, a high index of suspicion must be present to aid in the discovery of arterial lesions, oftentimes necessitating further evaluation of clinical parameters following treatment of venous stenoses [31].

Anastomotic and Juxta-anastomotic Lesions

Up to 50`% of lesions in patients with AV access for HD are located in the anastomotic and juxta-anastomotic regions, by far the most common location [32]. Fortunately, these lesions are typically easily diagnosed at fistulogram/graftogram via retrograde injection with manual occlusion of the venous outflow, allowing for concurrent treatment. Additionally, these lesions are readily visualized at US evaluation of the AV access, allowing for enhanced pre-procedure planning. The superficial nature and specific location of these lesions significantly simplify diagnosis and treatment compared to arterial lesions at other sites.

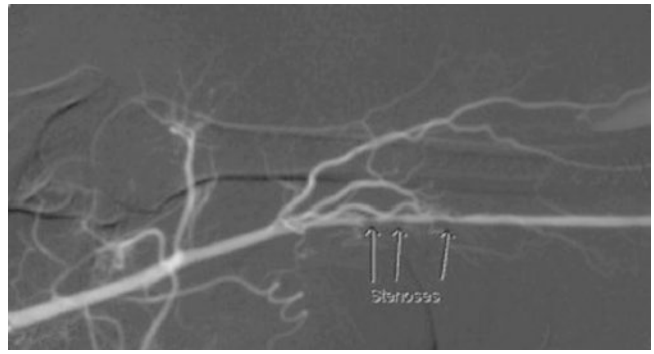

Fig. 23.4 Digital subtraction angiogram demonstrates segmental stenoses (labeled) of the left brachial artery in the inflow of the forearm AVF. This led to AVF dysfunction. Note no catheter is seen within the vessel, denoting that the arterial system was not accessed through the AV access

Central and Feeding Artery Lesions

In contrast, central or feeding artery stenoses present a diagnostic challenge, as lesions in these locations are not usually identified during the typical fistulogram/graftogram (Fig. 23.4). Stenoses in these locations can account for up to roughly 30–40% of lesions and are not uncommon [33]. If the index of suspicion for a central lesion is high, diagnosis may require retrograde cannulation of the aorta through the AV access to perform arteriography and runoff or an antegrade approach via arterial puncture at a site other than the AV access. Additionally, CT angiography may be helpful in pre-procedure diagnosis if clinical impressions suggest a central/feeding artery lesion.

Distal Artery Lesions

Distal arterial stenoses are less frequently encountered than juxta-anastomotic and central/feeding lesions. The association of peripheral arterial disease and general vasculopathy with the HD patient population predisposes these patients to diffuse arterial disease. Fortunately, these lesions are oftentimes more readily clinically apparent than central/feeding artery lesions [34]. Although a distal arterial stenosis will not have a direct effect on AV access function, it has the potential to induce devastating clinical consequences. These include hand ischemia or tissue loss in the extremity containing the AV access. For this reason, if there are symptoms attributed to arterial stenosis and the more common locations for disease demonstrate no evidence of disease, the distal arteries should be thoroughly evaluated. Another caveat that must be kept in mind is that distal arterial stenoses often coexist with abnormalities of the venous outflow. Treatment of venous outflow disease without addressing a distal arterial stenosis can inadvertently trigger a steal phenomenon [35]. This occurs because the low resistance to flow in the treated AV access preferentially shunts blood away from the vascular territories beyond the high-resistance distal arterial lesion. A thorough retrograde angiogram should demonstrate at least the immediate distal arterial segments and allow for avoidance of this scenario.

Lesions due to External Compression

External compression of the arterial inflow by adjacent anatomic structures is a rare cause of AV access dysfunction. Examples of potential situations are compression of the subclavian artery by a thoracic aortic aneurysm or a cervical rib. CT and MR are ideally suited for evaluation and diagnosis of external compression, as these modalities visualize all structures adjacent to the blood vessels in detail [19]. Endovascular treatment of these lesions alone is futile, as the underlying compression must be addressed. Surgical decompression is required. Occasionally, an arterial stenosis at the anastomotic or juxta-anastomotic region of a previous failed AV access in the same extremity acts as the direct cause of dysfunction of a downstream AV access and/or hand ischemia.

Management

Endovascular techniques are the mainstay of management of AV access dysfunction for both venous and arterial lesions. This approach allows for confirmation of the diagnosis and treatment in the same session and can lead to continued patency of the access. Endovascular treatments are safe and effective, can be performed on an outpatient basis in most instances, and can be repeated as needed should future problems arise [36]. In rare cases, recanalization of severe occlusive arterial stenosis with a guidewire fails, making surgical bypass a second-line treatment option. Especially in the case of arterial inflow disease, primary patency rates are excellent, with multiple studies documenting no requirement for additional treatment following successful angioplasty or stenting [37, 38].

Percutaneous Transluminal Angioplasty

Percutaneous transluminal angioplasty (PTA) is the main form of endovascular treatment. PTA is used in both venous and arterial structures. Interventionalists that regularly perform evaluation of HD AV access should have a definite familiarity with endovenous PTA, as it is commonly performed. PTA of arterial lesions varies somewhat from its venous counterpart, due to the underlying physiologic differences between artery and vein. Depending on the unique training pathway of the interventionalist, some individuals may not be as comfortable or familiar with arterial PTA. For example, common practice of endovenous PTA usually requires an oversized balloon under high pressure with a relatively long duration of inflation to achieve acceptable results. In contrast, for arterial angioplasty, a balloon appropriately sized to the vessel diameter is used, lower pressures are required, and less inflation time is necessary [39]. The arsenal of tools available for PTA is continuously expanding, with drug-coated balloons as an example. PTA of arterial lesions is associated with more potential complications than venous angioplasty. Potential complications include arterial dissection, occlusion, thrombosis, distal embolization, and rupture [40]. Despite the higher complication rate, successful angioplasty of arterial lesions carries a higher primary patency rate than venous treatments, which often require multiple repeated sessions to maintain a patent outflow. Complication rates, though higher than venous angioplasty, are nevertheless acceptable in light of the usually complicated medical comorbidities present in the HD population and are justified by avoidance of alternative less invasive surgical approaches. Operator experience also plays a role in complication rates, and as evaluation and treatment of the arterial portion of the AV access circuit become more routine, interventionalists will continue to become more adept at their performance.

Stents

Stents are a treatment option available as an adjunct to PTA. Following PTA, a significant residual stenosis may be seen. Also, lesions resistant to balloon dilatation are sometimes encountered during angioplasty (Fig. 23.5). In these cases, stenting would allow for effective restoration and preservation of adequate luminal diameter. Other cases in which stents are useful are in the setting of angioplasty complications. Should arterial dissection or rupture arise due to PTA, stents can be used to quickly and safely treat these lesions while preserving the native vascular channels and the AV access.

Stent Varieties

Available stent varieties continue to evolve, with an array of options tailored to certain clinical scenarios. These include variations in external design such as bare metal or covered as well as variations in delivery methods, such as self-expanding or balloon-mounted, in addition to other characteristics such as drug-eluting and flared stents as well as an assortment of stent grafts. Each of the available systems offers its own advantages and disadvantages, such as specific safety profiles, limitations, patency rates, and precision

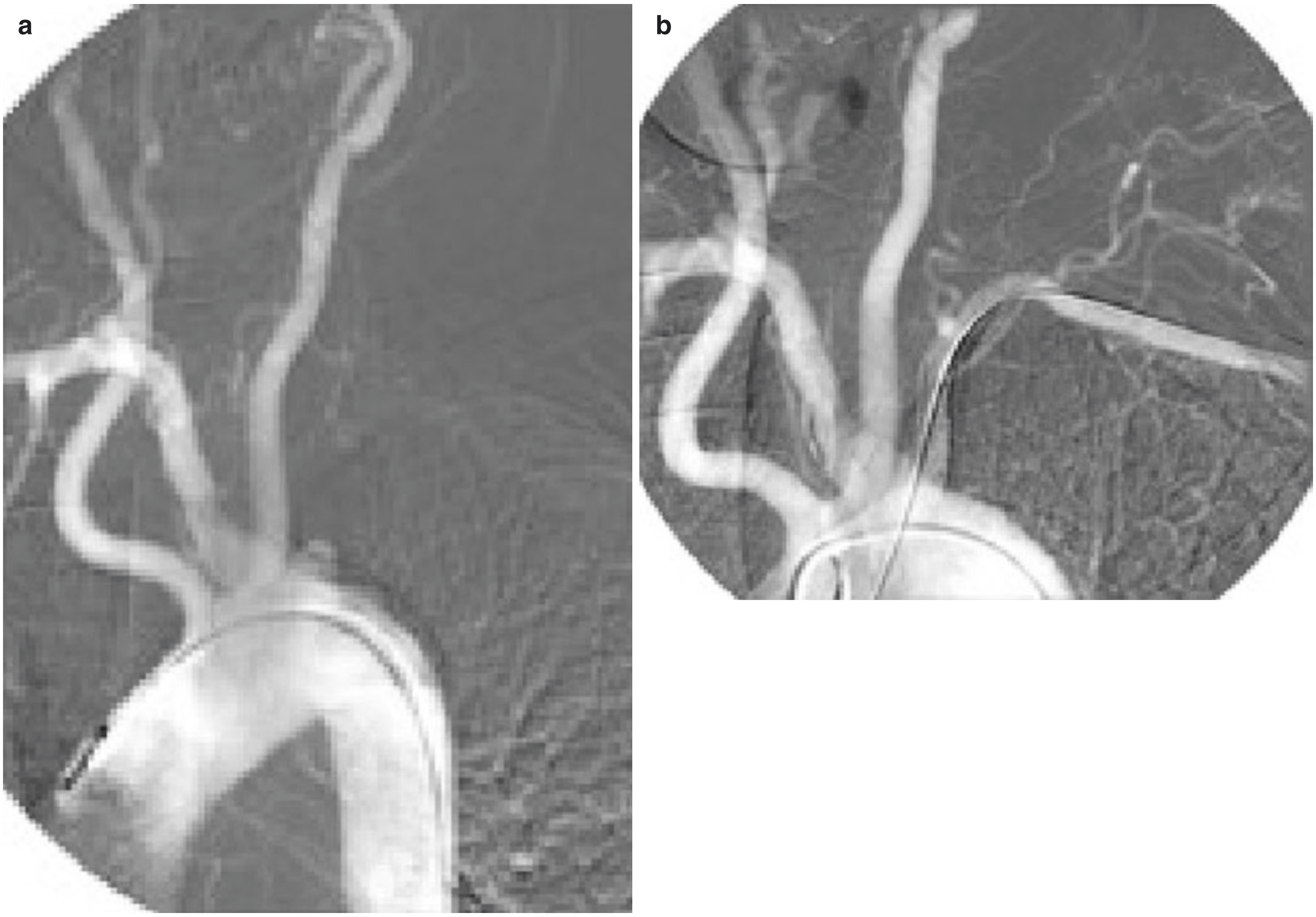

Fig. 23.5 (**a**) Digital subtraction angiogram demonstrates complete occlusion of the left subclavian artery. The patient has a left upper extremity AVF and presented with ischemic signs in the left upper extremity as well as AV access dysfunction. (**b**) The occlusion was successfully crossed, and a stent was placed across the closed segment, restoring patency and inflow to the left upper extremity

of delivery. Self-expanding stents generally have greater tensile and radial strength, while balloon-mounted stents allow for very precise delivery. There is a higher potential for stent fracture/malfunction when using balloon-mounted stents. Self-expanding stents may be preferred in the more central arterial tree. Newer stents have been designed with greater flexibility, and placement across joints or points of flexion has become more commonplace. This should, however, be avoided whenever possible as the risk of stent occlusion and fracture increases in such locations. Covered stents are preferred in the treatment of venous lesions due to higher patency rates in comparison to bare-metal stents [41]. Bare-metal stents are effective for treatment of arterial lesions and are commonly used for resistant or recoiling stenoses [42].

Angiographic Approach

As mentioned previously, common practice for angiography is to cannulate the AV access. Again, for treatment of arterial lesions, this requires retrograde cannulation across the anastomosis. This approach has been proven to be safe and effective and eliminates some potential complications associated with arterial puncture at other sites, such as pseudoaneurysm formation. The interventionalist can choose to access the arterial tree through a variety of routes, including the common femoral artery, the axillary artery, the brachial artery, and the radial artery. Studies have demonstrated that an antegrade approach is associated with increased rates of detection of the presence of inflow lesions relative to the retrograde approach [43]. Adjunct diagnostic imaging studies, such as CT or MR, can clarify the need for antegrade access prior to the angiographic procedure. Regardless of the approach, the basic principles of angiography should be practiced. This entails gaining arterial access and using a guidewire and catheter system to cannulate the vessel of interest under fluoroscopic guidance, allowing for injection of contrast material. Of import, when treatment is planned, guidewire access across the lesion undergoing PTA or stenting should be maintained at all times (Table 23.4 Management).

Table 23.4 Endovascular management

1. Access
Commonly through AV access
If site of arterial lesion known from prior noninvasive imaging, common femoral or other approach may be useful
2. Diagnosis
Depiction of the venous outflow, AV access, and arterial anatomy. Depending on access route, retrograde cannulation of central/feeding arteries may be necessary
3. Treatment
Guidewire access across lesion to be treated maintained at all times.
(a) PTA: Appropriately sized balloon based on vessel diameter; lower pressures/shorter inflation time than venous PTA.
(b) Stents: Used for resistant or recoiling stenoses and in the setting of complication management (vessel rupture)

Table 23.5 Anticoagulation recommendations

During PTA:
Use of heparin varies by institution
3000 units IV a reasonable dose, with titration to ACT >250 s
Following stent placement:
Immediate loading dose of clopidogrel (300 mg) followed by 75 mg daily for 6 months
Aspirin 81–325 mg daily

Anticoagulation

The use of anticoagulants during diagnostic and therapeutic angiography varies by institution. Although anticoagulation therapy with heparin is usually not required, the interventionalist may choose to administer a dose prior to angioplasty. When angiogram is performed from an antegrade approach in the arterial tree for treatment of a known stenosis, use of intra-procedure heparin may be prudent. If stents are placed, standard antiplatelet therapy with aspirin and clopidogrel should be initiated following the procedure (Table 23.5 Anticoagulation recommendations).

Conclusion

Arterial stenoses are increasingly recognized as significant contributors to AV access dysfunction. The HD population has a high degree of associated vasculopathy, which emphasizes the prevalence of arterial lesions in this setting. Additionally, the HD population continues to expand worldwide, with AV access creation as the ideal goal for initial access; consideration of arterial stenoses as a source of access dysfunction or failure is a critical component of patient evaluation [44]. Interventions, including PTA and stent placement, performed on arterial lesions typically have excellent results, with an up to 20% increase of flow in 90% of cases as well as superb long-term patency rates. However, diagnosis still poses a significant challenge, as many interventionalists do not visualize the entire arterial tree at fistulogram/graftogram. Noninvasive imaging may facilitate diagnosis in certain cases, but the gold standard remains angiography. Complete evaluation of the arterial tree, including the central arteries and feeding arteries as well as the juxta-anastomotic region, is crucial; however, this may be a time-consuming endeavor that also increases procedural risk. The exceptional clinical results obtained with endovascular treatment warrant a thorough evaluation in at least patients who are likely to have an arterial lesion. A combination of clinical and noninvasive imaging findings may allow for stratification of patients in this regard. The interventionalist should be familiar with the available approaches to arterial diagnosis, potential complications, and benefits of treatment in order to deliver the best possible care while minimizing adverse outcomes.

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