Overview of hemodialysis access and assessment

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Abstract

Objective To provide family physicians with an evidence-based overview on the various methods of vascular access for hemodialysis (HD) and to provide a framework for the clinical assessment of HD access.

Sources of information A MEDLINE literature search was conducted using the MeSH terms *arteriovenous fistula*, *arteriovenous graft*, *central venous catheter*, and *hemodialysis* (or *haemodialysis*), including all relevant English-language articles published between January 1995 and September 2021.

Main message The main types of permanent vascular access for HD are arteriovenous fistulas, arteriovenous grafts, and central venous catheters. A pragmatic, patient-centred approach is required when choosing the type of access for an individual. Common complications of vascular access creation include thrombosis, central venous stenosis, dialysis access steal syndrome, and arteriovenous fistula aneurysms.

Conclusion Family physicians play an important role in the clinical assessment and monitoring of HD vascular access. A thorough clinical assessment can detect a failing arteriovenous fistula and any associated complications, which can allow for prompt investigation and intervention to restore functionality, maintain access longevity, and improve patient quality of life.

Editor's key points

- A systematic history and examination can reliably identify most issues and complications associated with hemodialysis (HD) access.
- The management options for a failing or complicated HD access are predominantly percutaneous; however, open and hybrid surgical options are often required for recalcitrant lesions. Clinical monitoring allows for early detection of these issues and can lead to prompt intervention, thereby improving long-term access longevity.
- Family physicians are a vital resource in supporting HD-dependent patients and performing ongoing clinical monitoring of HD access.

The global incidence of kidney failure is rising in tandem with the prevalence of people receiving chronic dialysis.[1] Hemodialysis (HD) is the most common form of dialysis, with a worldwide prevalence of 89%, while peritoneal dialysis constitutes the remaining 11%.[1] The specific type of vascular access chosen for HD is a patient-centred decision, with arteriovenous fistulas (AVFs) being the preferred method as they are associated with lower rates of complications and have superior long-term durability.[2,3] However, AVFs require substantial resource investments to support their use, including preoperative imaging of suitable vessels, surgical creation, cannulation by experienced dialysis staff, and ongoing clinical surveillance. Alternative means of vascular access for HD, including arteriovenous grafts (AVGs) and central venous catheters (CVCs), may be chosen by a patient's dialysis team based on patient preference, comorbidities, and life expectancy. Since family physicians have consistent and long-term relationships with many of these patients, they are well positioned to help with vascular access surveillance. This article will discuss the various types of vascular access, with the aim of supporting family physicians who provide care to patients with AVFs.

Case description

Ms Z. is a 68-year-old woman who presents to her family medicine clinic with swelling in her right upper limb that developed over the past 2 months and is causing her discomfort. She is HD dependent via a right-sided brachiocephalic AVF. She also reports that she had been asked to increase her HD hours recently and there is greater difficulty in achieving hemostasis following cannulation.

What history and clinical examination findings can be used to identify any underlying issues with the AVF? How do you know if her AVF is threatened? What further investigations are warranted? What are potential management options?

Sources of information

A MEDLINE literature search was conducted using the MeSH terms *arteriovenous fistula*, *arteriovenous graft*, *central venous catheter*, and *hemodialysis* (or *haemodialysis*), with all relevant English-language articles published between January 1995 and September 2021 included.

Main message

Types of hemodialysis access

There are 3 main types of permanent vascular HD access: autogenous AVFs, AVGs, and tunneled CVCs.

Arteriovenous fistula. An AVF is the most durable form of vascular access for HD and is associated with the lowest rates of complications, including those of thrombosis and infection.[2,3] An AVF is created via a surgical anastomosis between an artery and a vein. Diversion of the high-flow arterial blood into the low-pressure vein results in progressive dilatation and wall thickening of the outflow vein, a process referred to as arterialization.[4] Arterialization eventually results in maturation, signifying the suitability of an AVF for cannulation and HD.[4] Maturation can often be determined using the *rule of 6s*,[5] which comprises the sonographic criteria detailed in **Table 1**. **Table 2** and **Figure 1** describe the most common AVF configurations.

An AVF requires approximately 6 weeks on average to mature,[6] with approximately 25% of AVFs never achieving maturation.[7] While it is hard to preempt the trajectory of a patient's kidney function, AVFs should ideally be created 3 to 6 months before their anticipated need.[8] This allows enough time for maturation and any surgical revision that may be required, with the goal of mitigating the need for HD via a CVC owing to its associated morbidity. Once an AVF has matured, several steps can be taken to care for it (**Table 3**).

Arteriovenous graft. An AVG is created by subcutaneously tunneling an expanded polytetrafluoroethylene graft, connecting an inflow artery and an outflow vein via a surgical anastomosis. Typically, AVGs are allowed to mature for at least 2 weeks before cannulation, thereby allowing incorporation into surrounding tissue.[4] Common AVG configurations are detailed in **Table 2** and **Figure 1**. Arteriovenous grafts are more prone to infection and thrombosis compared with autogenous AVFs, and they are therefore usually considered only when autogenous AVF options have been exhausted.[2]

Central venous catheter. Central venous catheters are used in patients requiring urgent HD who may be awaiting permanent access creation, access maturation, or kidney transplantation.[4] They are also used as permanent HD access in patients who have exhausted their AVF or AVG options, have severe cardiac disease, or have anticipated short life expectancies.[4]

Central venous catheters have many advantages, including a less demanding technical procedure (typically inserted by radiologists, nephrologists, and intensivists, rather than surgeons), lower resource usage, potential for immediate HD provision, and no need for percutaneous cannulation (unlike AVFs and AVGs), making them a convenient form of vascular access. They could also be preferred as a long-term option in low-resource settings or in patients with multiple comorbidities, limited life expectancy, or needle phobia. However, CVCs are often not the optimal choice owing to their tendency for higher rates of infection, increased risk of developing central venous stenosis, and poor long-term durability secondary to thrombosis.[9]

Central venous catheters come in 2 varieties: nontunneled catheters and tunneled catheters.

Nontunneled catheters: These are used in critically ill patients and are designed for short-term dialysis.[4] These catheters typically need to be removed before discharge from hospital owing to the risk of catheter dislodgement and infection.

Table 1. Rule of 6s: *Sonographic criteria for AVF maturation.*

CRITERIA	DESCRIPTION
Outflow vein calibre ≥6 mm on ultrasound	Outflow veins will progressively dilate over time. Generally, a calibre of 6 mm is indicative of an outflow vein that is easy to cannulate and will provide sufficient flow for hemodialysis
Outflow vein depth <6 mm on ultrasound	If outflow veins are too deep within the subcutaneous tissues, they may be difficult to cannulate. Those that are too deep may require further surgery for superficialization
Blood flow >600 mL/min	Sufficient blood flow is required through the outflow vein to support adequate hemodialysis
Cannulation >6 wk postcreation	It is often best to wait at least 6 wk postcreation before cannulating an AVF to allow it to arterialize appropriately. This can minimize cannulation-related complications such as hemorrhage or false aneurysms

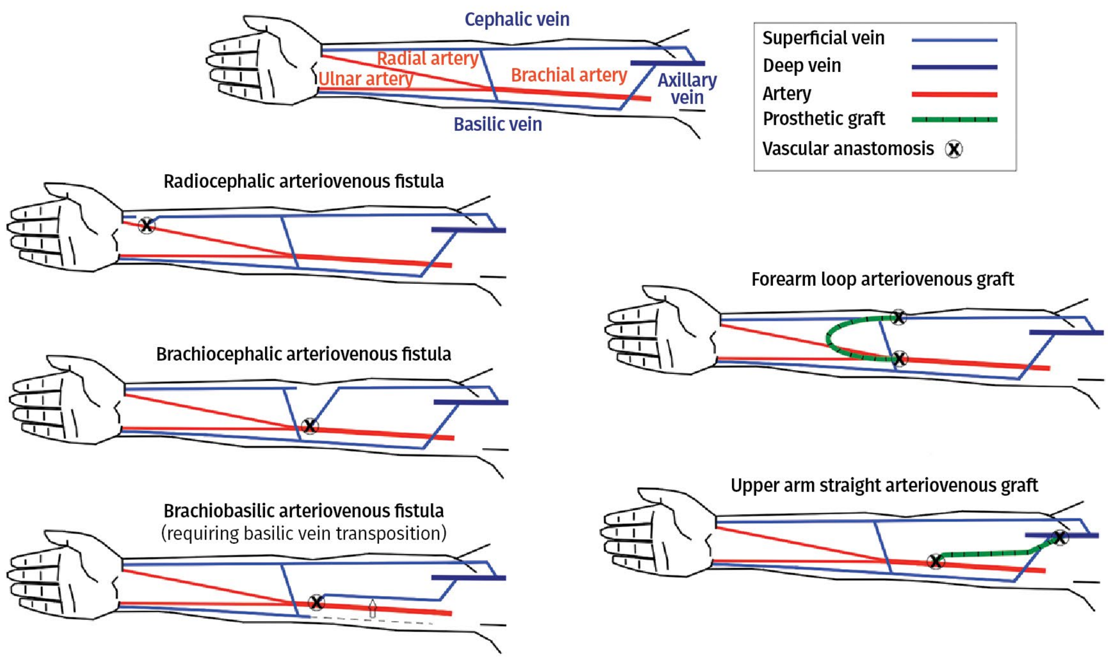
AVF—arteriovenous fistula.

Table 2. Common autogenous AVF and AVG configurations

ACCESS TYPE	ACCESS CONFIGURATION	DESCRIPTION
Autogenous AVF	Radiocephalic (Brescia-Cimino-Appel)	An anastomosis is created between the radial artery and the cephalic vein at the wrist. The outflow vein is cannulated in the forearm
	Brachiocephalic	An anastomosis is created between the brachial artery and the cephalic vein at the antecubital fossa. The outflow vein is cannulated in the upper arm
	Brachiobasilic (requiring basilic vein transposition)	An anastomosis is created between the brachial artery and basilic vein in the antecubital fossa. This requires a more complex operation as the basilic vein is a deep structure and will need to be mobilized to a more superficial position in the arm to allow it to be cannulated. This procedure can be performed in 1 or 2 stages. The outflow vein is cannulated in the upper arm
AVG	Forearm loop graft (brachial artery to median cubital vein or cephalic vein)	A prosthetic graft connects the brachial artery and the cephalic vein or median cubital vein within the antecubital fossa. The graft is tunneled as a loop in the proximal forearm
	Upper-arm straight graft (brachial artery to axillary vein)	A prosthetic graft connects the brachial artery in the antecubital fossa with the axillary vein in the proximal upper arm. The graft is tunneled as an arc through the upper arm

AVF—arteriovenous fistula, AVG—arteriovenous graft.

Figure 1. Common arteriovenous fistula and arteriovenous graft configurations



Tunneled catheters: These catheters can be used for long-term HD.[4] The internal jugular vein is the preferred access vessel,[10] with the catheter tunneled subcutaneously over the clavicle and exiting via the skin of the anterior chest wall. The subcutaneous tunnel is sealed by a cuff collar to reduce the risk of catheter infection and dislodgement.[11]

Assessment of vascular access

An HD vascular access assessment is composed of a history, an assessment of arterial inflow, and an assessment of venous outflow. **Box 1** provides an overview of the assessment.

Variations in the examination findings usually represent a complication and may indicate a functionally threatened AVF. Specific complications and their associated examination findings are outlined in **Table 4**.

Arteriovenous fistula complications

Failing or thrombosed access. The most common reason for vascular access failure is thrombosis.[12] The aim of regular clinical assessment is to detect failing

Table 3. Strategies for AVF maintenance and preservation of future access sites

STRATEGY	DESCRIPTION
Consistent assessment for a thrill	Patients should be taught to examine for a thrill on a daily basis. If there is loss of thrill or a change in character, they should be advised to present to a vascular access clinic or hospital
Avoidance of blood pressure assessment on the AVF arm	Patients should remind health care workers never to take blood pressure readings from the AVF arm as this can compress the outflow vein, potentially causing thrombosis
Preservation of the AVF outflow vein	Patients should remind health care workers to avoid IVC or phlebotomy of the AVF outflow vein
Preservation of the cephalic and basilic veins of the arm for future access options	Patients should remind health care workers to avoid IVC of the cephalic, basilic, and antecubital veins to preserve future AVF sites, particularly in the nondominant arm as this is preferentially used for AVF creation. Any essential IVC and phlebotomy should occur in the dorsum of the dominant hand where possible
Consistent clinical monitoring and surveillance of the AVF	Medical practitioners should perform a brief assessment (history and examination) of the AVF on a consistent basis. If any complications are detected on assessment, this should be followed by duplex ultrasonography to assess for arterial inflow or venous outflow lesions that may be amenable to treatment. Alternatively, patients can also be directly referred to a vascular access service

AVF—arteriovenous fistula, IVC—intravenous cannulation.

Box 1. Hemodialysis vascular access assessment: *Targeted questions to ask prior to examining a patient's HD access.*

History

- Have you been recommended to increase your dialysis hours lately? (Suggestive of recirculation and inefficient HD clearance, which may be secondary to venous outflow stenosis. Longer HD sessions may also be required to achieve the requisite ultrafiltration [fluid removal] and target weight)
- Is it difficult to achieve hemostasis at the cannulation sites? (Suggestive of venous outflow stenosis)
- Do you experience pain in the arm at rest or during exertion? Does this pain worsen during dialysis? (Suggestive of DASS)
- Is the thrill palpable? If not, when was the thrill lost? (Suggestive of AVF or AVG thrombosis or nonmaturation)

Assessment of arterial inflow

- *Look*: Inspect for signs of arterial insufficiency such as pallor, atrophy of the limb, or tissue loss (ulceration or gangrene of the hand)
- *Feel*: Palpate for the presence of the upper limb pulses. Assess general limb perfusion by checking temperature and capillary refill time, and by assessing for sensorimotor impairment
- Use pulse oximetry, which is an ancillary test where the peripheral oxygen saturation of the tested limb can be compared with that of the contralateral limb, giving an indication of arterial perfusion. This is particularly useful if there are concerns regarding DASS

Assessment of venous outflow

- *Look*: Inspect for signs of venous hypertension, which includes edema of the limb, face, or breast as well as the presence of prominent superficial collateral veins over these same regions. Severe cases may also have skin pigmentation or venous stasis ulceration. Inspect the outflow vein for its calibre and any focal dilatations
- *Feel*: Palpate the outflow vein for its consistency and for a thrill. The palpation characteristics of a mature and functional AVF outflow vein are soft and compressible consistency that indicate patency and arterialization. Presence of a robust, continuous thrill distal to the anastomosis indicates adequate and unobstructed flow. The thrill starts at the site of the anastomosis and progresses for a few centimetres up the outflow vein. The presence of a pulse without a thrill is an abnormal finding and is suggestive of venous outflow obstruction
- *Listen*: Auscultate the outflow vein for a bruit—this supplementary test is used to confirm the findings from palpation. A functional AVF will have a continuous and low-pitched bruit. Like the thrill, the bruit will be loudest at the anastomosis and diminish more proximally toward the shoulder but should maintain a consistent character

AVF—arteriovenous fistula, AVG–arteriovenous graft, DASS—dialysis access steal syndrome, HD—hemodialysis.

Table 4. Potential outflow vein complications and associated examination findings

OUTFLOW VEIN COMPLICATION	EXAMINATION FINDINGS
Arterial inflow stenosis or nonmaturing outflow vein	Will present as a small-calibre outflow vein with a weak or absent thrill
Venous outflow stenosis (involving either the outflow vein or the central veins)	Will present as a hyperpulsatile outflow vein upstream to the obstruction with loss or a change in character of the thrill. Additionally, the outflow vein will be noncollapsing on arm elevation
Thrombosis of the outflow vein	Will present as an indurated, noncompressible, tender outflow vein with no thrill
Aneurysms or pseudoaneurysms of the outflow vein	Will present as focal dilatations of the outflow vein. These dilatations may be associated with cannulation sites but alternatively may be a consequence of venous outflow stenosis

or vulnerable AVFs to facilitate early intervention to prevent thrombosis and restore functionality. If abnormal signs are detected on clinical examination, it can be followed by a duplex ultrasound (DUS), which is used to interrogate any arterial inflow or venous outflow lesions.[13] Following preliminary assessment, the patient's dialysis team (ie, dialysis nursing staff, vascular access coordinators, and nephrologists) are generally the first-line resource to help expedite further assessment, diagnostic testing, and intervention.

There are 3 primary reasons for a failing or thrombosed AVF: the first is inadequate venous outflow, which occurs primarily owing to acquired stenoses of either the outflow vein or the draining central veins. Stenoses often occur because of neointimal hyperplasia in response to the hemodynamic changes from arterialized blood being routed through the venous system.[14] The second is inadequate arterial inflow, which occurs because of occlusive disease in the arteries of the upper limb that feed the AVF.[15] The third are medical factors, including reduced cardiac function, hypotension,[16] or hypercoagulable states.[17]

Most arterial and venous lesions responsible for failing access are amenable to endovascular intervention in the form of percutaneous transluminal angioplasty.[18,19] Some lesions may require a stent or an open surgical revision.[20-22]

Venous hypertension. Central venous stenosis or occlusion may present clinically as edema of the limb or edema of the ipsilateral neck, face, breast, and chest wall. Severe cases may also be complicated by venous stasis ulceration. Central venous stenosis can occur by neointimal hyperplasia of central veins secondary to altered hemodynamics following AVF creation and by current or previous CVC access. The diagnosis is made based on a computed tomographic venogram or a catheter-based fistulogram. The primary treatment modality is endovascular intervention in the form of percutaneous transluminal angioplasty, which can restore central venous outflow.[23,24]

Dialysis access steal syndrome (DASS). Most AVFs steal arterial blood from the limb by diverting blood flow from the artery perfusing the limb to the venous outflow of the AVF.[25] However, it is the degree of steal that is important. Clinically significant DASS occurs when there is insufficient antegrade arterial blood flow to perfuse the limb.[25] **Table 5** details DASS severity grades.

Patients with suspected DASS can be investigated with DUS, which may demonstrate reversal of flow in the segment of the artery distal to the anastomosis as well as high flow volumes through the outflow vein (>800 mL per min in AVFs[26]). For patients with clinically mild DASS (grade 1 or 2), management is often conservative, with many patients eventually experiencing improvement in symptoms over time.[27,28] Severe DASS (grade 3 or 4) usually warrants acute surgical treatment to improve arterial perfusion, reduce venous outflow, and prevent limb loss.[28,29]

Arteriovenous fistula aneurysms. Generalized outflow vein enlargement is a normal finding; however, focal dilatations represent an outflow vein aneurysm. There are 2 types of aneurysms: a true aneurysm, which is a dilatation involving all 3 layers of the vein[30] and is generally related to degenerative changes in the vessel that may be caused by venous outflow stenosis[31]; and a false aneurysm, which is caused by a small tear in the outflow vein (usually iatrogenic from cannulation), resulting in a persistent defect that allows blood flow into the subcutaneous tissues outside of the wall of the outflow vein.[30]

A DUS can be used to identify both true and false aneurysms while also investigating the underlying cause (eg, venous outflow stenosis). Surgical management is indicated for the management of complications such as rapid enlargement, overlying skin necrosis, or spontaneous bleeding, while uncomplicated aneurysms can often just be monitored.[4,12] Operative management will depend on the morphology; true aneurysms commonly require excision of the aneurysmal segment followed by reconstruction of the outflow vein (sometimes requiring an interposition graft),[32] while false aneurysms are commonly repaired with primary closure of the defect in the vessel wall.[33,34]

Case resolution

Ms Z.'s right upper limb and her brachiocephalic AVF are comprehensively examined. She has unilateral pitting edema and the outflow vein of the AVF has lost its thrill and is pulsatile. Based on the examination findings, a venous outflow obstruction is suspected that puts the AVF at risk of thrombosis and

Table 5. DASS grades of severity

GRADE	DESCRIPTION
1	Cool or pale limb that is asymptomatic
2	Intermittent claudication of the limb during exertion or hemodialysis
3	Rest pain of the limb. Rest pain can often be worst at night and typically improves with dependency
4	Tissue loss of the limb (including ulceration or gangrene)

DASS—dialysis access steal syndrome.

failure. A DUS is organized and shows a patent outflow vein without any stenotic lesions. Given the DUS findings, the suspected diagnosis is a central venous obstruction that cannot be diagnosed definitively on DUS. She is referred to a vascular access service and undergoes a catheter-based fistulogram that shows a high-grade stenosis of the right brachiocephalic vein that is treated successfully with percutaneous transluminal angioplasty. Ms Z. is recommended to increase her dialysis hours as a temporary strategy to achieve adequate clearance and fluid removal (in the setting of inefficient HD secondary to the venous outflow obstruction) while undergoing AVF evaluation. Following intervention, the outflow vein of her AVF regains its thrill, the upper limb edema subsides, and the HD adequacy improves over the next few weeks.

Conclusion

With the increasing prevalence of people receiving HD, family physicians have an opportunity to play an important role in the clinical assessment and monitoring of HD vascular access. A thorough clinical assessment can detect a failing AVF and any associated complications, which can allow for prompt investigation and intervention to restore functionality, maintain access longevity, and ultimately improve patient quality of life.

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Contributors

All authors contributed to the literature review and interpretation, and to preparing the manuscript for submission.

Competing interests

None declared

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