

US Evaluation of Arteriovenous Fistula Complications in the Emergency Setting

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Abstract

Arteriovenous fistulas (AVFs) are the preferred vascular access for hemodialysis, but they are prone to complications that frequently present in the emergency department. Timely recognition of these problems is essential to preserve access patency and avoid life-threatening events. Bedside US is uniquely suited to this setting because it is rapid, repeatable, and provides direct visualization of the access, surrounding soft tissues, and arterial and venous hemodynamics. This review offers a practical, stepwise US approach for the emergency evaluation of AVFs and for each major complication. We summarize key clinical presentations, high-yield B-mode and Doppler findings, common pitfalls, and typical management pathways. Illustrative cases, tables, and checklists highlight how integrating clinical information with standardized US techniques can help differentiate overlapping entities. By adopting a structured US protocol and recognizing these characteristic imaging patterns, emergency physicians and radiologists can improve diagnostic confidence, streamline consultation with nephrology and vascular surgery, and contribute to safer and more efficient care for patients with AVFs.

Keywords: hemodialysis, arteriovenous fistula, emergency US, Doppler US

Introduction

End-stage renal disease represents a substantial and escalating global public health challenge, consuming considerable health care resources worldwide. In 2023, the global point prevalence of kidney failure requiring replacement therapy was estimated at 4.59 million, with type 2 diabetes and hypertension together accounting for 40.6% of cases.¹ In this expanding hemodialysis population, the quality and durability of vascular access are key determinants of long-term outcomes.

The arteriovenous fistula (AVF) is the preferred vascular access for hemodialysis owing to its lower complication rates and superior longevity compared with

arteriovenous grafts and central venous catheters.² Despite these advantages, AVFs remain susceptible to a substantial burden of dysfunction and failure. Early failure rates range from 20% to 60%,³ and, according to the United States Renal Data System, the cumulative incidence of primary unassisted patency loss 2 years after AVF creation is 48.8%, while losses of primary assisted and secondary patency are 18.6% and 2.7%, respectively.⁴ This frequency of failure, combined with the persistent requirement for maintenance interventions, generates a significant volume of acute clinical presentations to emergency departments.

Compared with CT or MR angiography, US is more widely available, cost-effective, and can be performed at the

bedside.^{5,6} In addition to its diagnostic role, US plays a critical part in preoperative planning, postoperative surveillance, and guiding interventional procedures. Duplex Doppler evaluation provides essential hemodynamic data, such as peak systolic velocity (PSV), PSV ratios across stenotic segments, and volumetric flow estimations. These parameters serve as reproducible markers of access dysfunction and help distinguish clinically significant from incidental findings. Consequently, comprehensive AVF ultrasonography is a core competency for radiologists in the emergency care pathway, and adherence to a standardized bedside protocol improves reproducibility and expedites specialty consultation.

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Disclosures: The authors have no conflicts of interest to disclose. None of the authors received outside funding for the production of this original manuscript and no part of this article has been previously published elsewhere.

Emergency Department Evaluation and Systematic Scanning Protocol

Proficiency in the imaging evaluation and characterization of hemodialysis access is essential for the radiologist, as accurate diagnosis directly guides clinical management, preserves the long-term functionality of this vital access, and associated morbidity.

Common emergency department presentations for suspected AVF complications include pain, swelling, erythema, a diminished or absent thrill, or bleeding at the access site.⁷

The examination should proceed in a logical sequence:

- During the initial patient encounter, a simple handshake is not only a gesture of courtesy but also a functional test. It allows for the assessment of distal hand temperature, sensation, and motor function, helping to identify signs of distal ischemia.⁸
- A systematic visual inspection of the skin and soft tissues overlying the AVF is imperative. This initial assessment serves to exclude superficial pathologies, such as cellulitis or skin ulceration, which may mimic or coexist with underlying access complications.
- Palpation and auscultation subsequently confirm a reduced or absent thrill or an abnormal bruit. The presence of warmth, tenderness, or drainage should be documented, as it may influence both management (antibiotic therapy) and the sonographic technique. Furthermore, a simple functional test like the Arm Elevation Test can confirm adequate venous outflow in AVFs if the access collapses upon elevation.⁹
- Adapt positioning to patient comfort and clinical status. For patients with kyphosis, orthopnea, or severe respiratory compromise, a semi-recumbent position is preferable.¹⁰ The presence of traumatic scars or neurological deficits may necessitate

examining the limb in pronation rather than the standard supination.

- Document the access side/type, date of creation, history of cannulation difficulties, and prior interventions.

A concise, stepwise summary of this bedside US approach for emergency evaluation of AVFs, highlighting key scanning phases and the main reportable items, is presented in Table 1. A representative Doppler sampling strategy and volume-flow measurement technique for a brachiocephalic AVF is illustrated in Figure 1.

Complications of Arteriovenous Fistula

The management of acute complications associated with AVFs in the emergency department relies heavily on rapid diagnostic imaging to inform immediate therapeutic decisions. US is considered the first-line imaging technique due to its noninvasive, repeatable, and cost-effective nature, serving as a critical diagnostic adjunct to the physical examination.¹⁴ Table 2 provides a rapid reference of each major AVF complication with its typical emergency department presentation, key diagnostic US findings, and reported incidence. Complications are commonly classified based on their time of occurrence and functional outcome: early events, or primary failure, refer to permanent access failure before it achieves suitability for hemodialysis (typically within 3 months) due to causes such as insufficient inflow or inappropriate remodeling, while late events, leading to secondary failure, occur in an access that previously met the criteria for successful dialysis.³

Thrombosis

Thrombosis is the most common acute event leading to access failure or loss of function. In approximately 75% of cases, it is associated with venous outflow

stenosis, with thrombophilia identified in approximately 9% of patients experiencing recurrent thrombosis episodes.³

Venous neointimal hyperplasia is the principal pathophysiological mechanism. Other factors include excessive access compression, persistent hypotension, hypovolemia, and coagulation anomalies related to chronic kidney disease. Clinically, patients present with acute pain, swelling, and loss of bruit or thrill. Prompt recognition is essential as salvage rates decrease rapidly with time.

On grayscale US, acute thrombi appear as hypoechoic or anechoic intraluminal material, while chronic thrombi become more echogenic. Doppler demonstrates absent flow within the affected segment, and compression confirms noncompressibility of the vein (Figure 2).

The thrombotic process typically involves the anastomotic region and the draining vein; arterial involvement is uncommon and generally suggests underlying atherosclerotic, iatrogenic, or inflammatory pathology. Surgical thrombectomy historically represented the standard management for thrombosed arteriovenous grafts and fistulas. In contemporary practice, percutaneous endovascular approaches have been increasingly employed.¹⁹

Stenosis

Stenosis is the most frequent underlying pathology that affects access. Pathogenesis involves a maladaptive vascular remodeling process, primarily driven by neointimal hyperplasia in response to abrupt changes in hemodynamic forces and wall shear stress. This process progressively manifests as luminal narrowing.²⁰

Patients may present with clinical indicators suggestive of access dysfunction, including difficult cannulation, prolonged bleeding after needle removal, or ipsilateral limb edema. Physical examination, however, demonstrates significant limitations in reliably identifying underlying stenosis.

Table 1. Emergency Arteriovenous Fistula US Quick Protocol: Stepwise Approach and Key Reportable Items

EXAM PHASE	KEY ACTIONS	REPORTABLE ITEMS
Pre-scan	- Use a high-frequency (7-12 MHz) linear array transducer for superficial segments of the fistula - Use a small-footprint curvilinear (5-8 MHz) or phased-array (2-5 MHz) probe to assess deep/central veins (eg, subclavian, brachiocephalic, superior vena cava) via a supraclavicular or sternal-notch window¹¹ - Optimize color settings (PRF, gain, box size) - Maintain a Doppler angle $\leq 60^\circ$	Access side/type, time of presentation, and brief chief complaint (pain/swelling/bleeding/loss of thrill)
(1) Venous survey	- Scan superficial and deep veins with and without compression; confirm respiratory phasicity - Obtain a comparative spectral trace from the contralateral subclavian	- Venous compressibility and phasicity - Presence/absence of intraluminal echogenic material; when present, document noncompressible echogenic material and its cephalic extent - Save one B-mode, one color, and one spectral image Goal: Starting with the venous survey is a high-yield strategy that addresses one of the most common complications (thrombosis or vein stenosis).
(2) Arterial survey	- Evaluate subclavian $\rightarrow$ brachial $\rightarrow$ radial/ulnar - Use color mapping to place spectral samples away from turbulence	- Near the anastomosis: low-resistance, high-velocity monophasic inflow - Distal (radial/ulnar): triphasic high resistance Goal: Rapidly confirm the expected pattern. Any loss of monophasic inflow proximally, absence of triphasic high-resistance distal, parvus-tardus or marked velocity asymmetry should raise suspicion for a significant lesion.
(3) Arteriovenous fistula functional assessment	- Perform grayscale, color, and pulsed-wave Doppler of the inflow artery, anastomosis, and outflow vein, with explicit annotation of each sampling site¹¹ - Keep Doppler angle $\leq 60^\circ$, center the gate, and avoid turbulent jets - Archive one labeled B-mode, one color, and one spectral image for each site (inflow, anastomosis, outflow)	- Peak systolic velocity at predefined sites (pre-, intra-, and post-anastomotic) and peak systolic velocity ratio across suspected lesions¹² - Flow directionality in distal arteries and in the outflow vein - Venous volume flow measured in a straight venous segment proximal to the anastomosis; average 3-5 samples with angle $\leq 60^\circ$; typical adequacy for mature arteriovenous fistulas: ~ 600-1200 mL/min¹³ Goal: Detect clinically significant arteriovenous fistula dysfunction (eg, reduced venous volume flow or abnormal inflow/outflow waveforms/directionality).

The sensitivity of physical examination for detecting arteriovenous graft stenosis is notably low, ranging from 36% to 57%.²¹

Digital subtraction angiography definitively diagnoses critical stenosis, defined as a luminal diameter reduction exceeding 50% relative to an adjacent normal vascular segment.³ Correspondingly, identifying a hemodynamically significant stenosis with sonography requires a multimodal approach encompassing morphological, hemodynamic, and functional parameters (Figure 3). This comprehensive assessment includes precise vessel lumen measurements, quantitative analysis of PSV, PSV ratio, and volumetric flow

quantification. The specific thresholds used to define hemodynamically significant stenosis are summarized in Table 3, and the most common sites of stenosis and their clinical implications are presented in Table 4. Treatment typically consists of percutaneous transluminal angioplasty to restore flow, although highly resistive lesions, such as juxta-anastomotic stenosis, may require surgical revision.

Vascular Steal Syndrome

Ischemic steal syndrome, also known as vascular steal syndrome, is defined as hand or finger pain caused by hypoperfusion (reduced blood flow) distal

to the AVF access. The incidence of symptomatic steal syndrome ranges from 0.25% to 20%, with incidence strongly correlated to anastomosis location. Forearm accesses demonstrate lower rates (0.25-1.8%) than brachial accesses (4-9%), where higher flow volumes predispose to ischemic complications and approximately 4% of patients require surgical intervention for steal syndrome following access creation.²² Key risk factors include diabetes, female sex, upper arm fistulas, peripheral arterial disease, and advanced age.

Patients may develop ischemic symptoms such as rest pain, paresthesia, digital ulcers, or even necrosis. On

Figure 1. Representative spectral Doppler assessment of a brachiocephalic arteriovenous fistula. (A) Spectral Doppler of key segments. The proximal brachial artery (inflow) shows a low-resistance waveform with persistent diastolic flow. The cephalic vein (outflow) is arterialized, with high-velocity signal and color turbulence. Distal radial and ulnar arteries retain the expected triphasic, high-resistance pattern of a resting limb. (B) Volume-flow quantification. The upper panel illustrates the measurement of venous outflow in a straight cephalic vein segment a short distance to the anastomosis, avoiding valves and branches. The lower panel demonstrates corroborative inflow assessment in the brachial artery proximal to the anastomosis. Average 3-5 samples and report site and value.

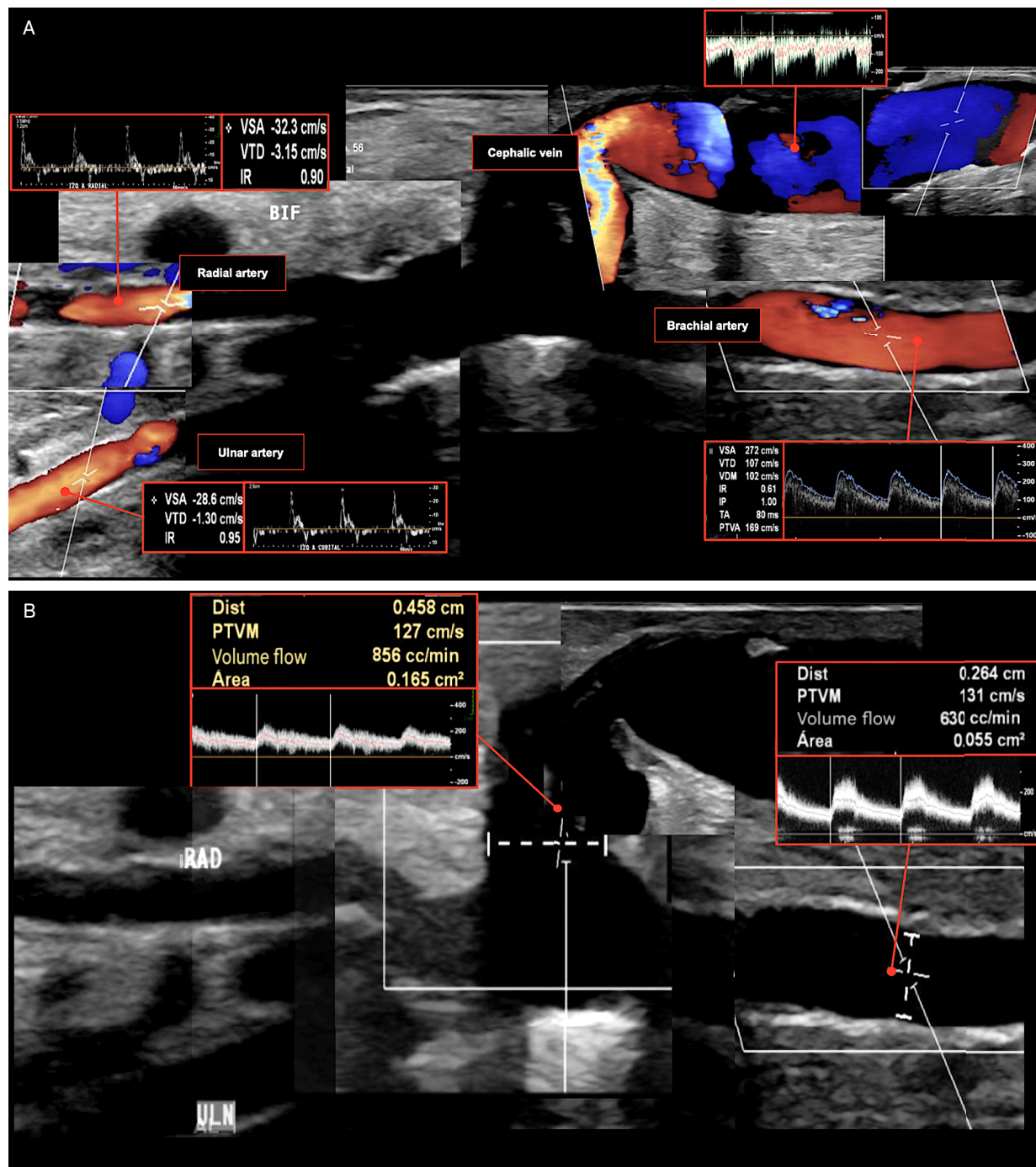


Table 2. Complications of Arteriovenous Fistulas: US Fast Guide

COMPLICATION	EMERGENCY DEPARTMENT CLINICAL PRESENTATION	KEY DIAGNOSTIC US FAST GUIDE FINDINGS	RATE/INCIDENCE
Thrombosis	- Sudden loss of thrill/bruit. - Inability to dialyze - Pain at the site of thrombosis	Absent or markedly reduced color Doppler flow within the fistula or graft; echogenic intraluminal thrombus; loss of normal spectral signal; and loss of compressibility in the involved segment	17-25% ⁶
Stenosis	- Gradual loss or change in thrill/bruit - Difficult cannulation, low dialysis flow, and prolonged post-dialysis bleeding - Arm or hand swelling in advanced cases	Focal luminal narrowing with color aliasing and post-stenotic turbulence; peak systolic velocity increases across the lesion with reduced flow distally	14-42% ⁶
High-output cardiac failure	Dyspnea, orthopnea, and peripheral edema	Markedly elevated access volume flow with very low-resistance arterial waveform in the feeding artery; large caliber of inflow and outflow vessels	12.2-17% ⁶
Aneurysm/pseudoaneurysm	- Palpable pulsatile mass along the access - Local pain, rapid enlargement, and overlying skin thinning or ulceration - Difficult cannulation	True aneurysm: fusiform dilatation of the access Pseudoaneurysm: saccular outpouching connected by a narrow neck showing “to-and-fro” waveform	4% ¹⁵
Steal syndrome	- Hand pain, coldness, and pallor, often worse during dialysis - Paresthesias or weakness of the hand - In severe cases, rest pain, tissue loss, or digital gangrene	High-flow, low-resistance waveform within the fistula with diminished, dampened, or even reversed flow in the distal artery	4% severe ischemia that requires reintervention 10-20% patients develop pain or paresthesias¹⁶
Infection	- Local erythema, warmth, swelling, and tenderness over the access - Purulent drainage from puncture sites - Fever, chills, or sepsis in severe cases	Hypoechoic or complex perivascular fluid collection around the fistula; thickened, heterogeneous vessel wall; increased soft-tissue vascularity on color Doppler; and possible gas with dirty shadowing or organized abscess	2-3% ⁶
Venous hypertension	- Painful, persistent arm and hand swelling - Dilated, tortuous superficial veins; skin discoloration or ulceration of the distal limb	Dilated outflow and collateral veins with sluggish, nonphasic flow	Uncommon 0.03 events per 1000 patient days¹⁷
Hemorrhage	- Acute external bleeding from puncture site or ruptured aneurysm - Expanding pulsatile hematoma - Hypotension, tachycardia, and signs of hemorrhagic shock in severe cases	Perivascular heterogeneous collection consistent with hematoma; focal wall defect with color Doppler jet extravasating into surrounding soft tissues	Uncommon The incidence of fatal vascular access hemorrhage episodes is reported to be less than 1 episode per 1000 dialysis patient-years¹⁸

Figure 2. Acute cephalic vein thrombosis in a radiocephalic arteriovenous fistula. A 29-year-old man presented with left upper-limb swelling after hemodialysis. Grayscale and compression US show noncompressible hypoechoic thrombus within the cephalic vein with absent color/spectral flow, extending proximally and ending 5 cm before the subclavian vein. Adjacent vessels, including the basilic and brachial veins, remain patent.

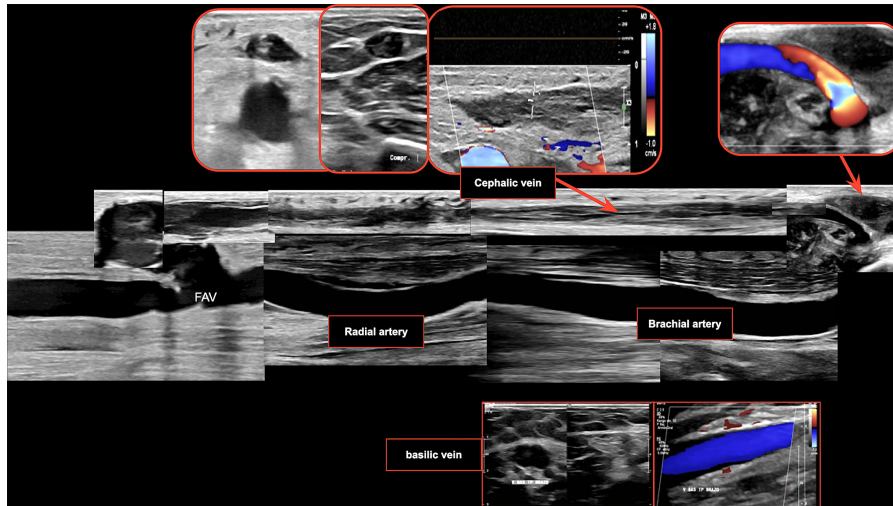
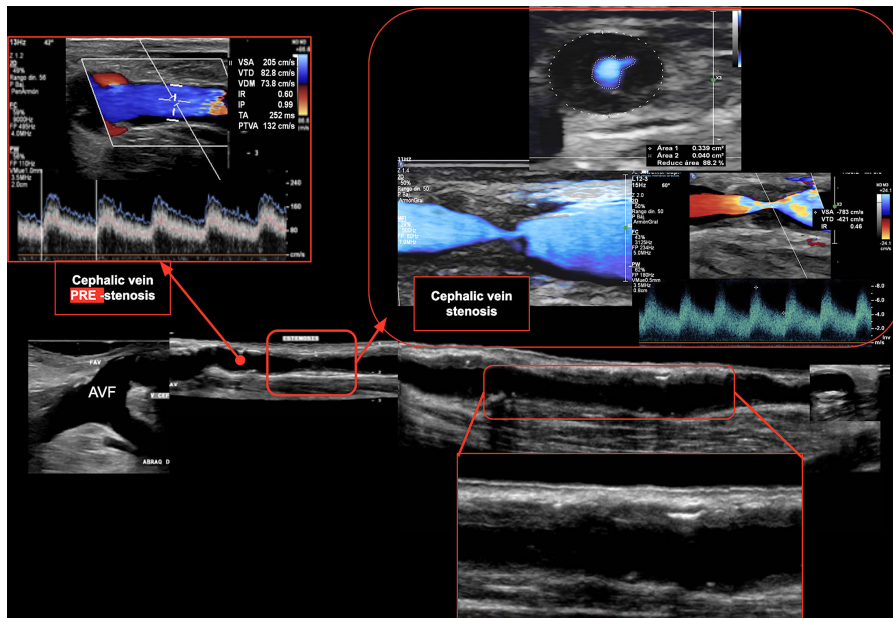


Figure 3. Stenosis in a brachiocephalic arteriovenous fistula. A 39-year-old man presented with a 1-month history of left upper extremity pain and edema. Color Doppler demonstrates significant luminal narrowing with aliasing in the mid-cephalic vein. Spectral analysis reveals a peak systolic velocity of 783 cm/s within the stenosis, with a pre-stenotic velocity of 205 cm/s, yielding a peak systolic velocity ratio of 3.7—consistent with significant stenosis. The sonographic appearance of intimal thickening with calcifications of the cephalic vein suggests chronic venous wall injury.



US, retrograde diastolic flow in distal arteries is the hallmark finding, which normalizes upon manual compression of the fistula (Figure 4).⁷ Flow volume allows differentiation between high-flow steal, in which a brachial-based arteriovenous access diverts an excessive volume of

blood away from the hand, and low-flow steal, in which distal hypoperfusion is driven by arterial inflow stenosis or severe peripheral small-vessel disease rather than excessive shunting. In high-flow steal, flow-reducing procedures such as revision using distal inflow (RUDI) (which

typically reduces access flow by about 50%) or proximalization of arterial inflow (PAI) are used to decrease access flow, while in low-flow steal the priority is to correct inflow disease (angioplasty or bypass).

High-Output Cardiac Failure

High-output cardiac failure (HOCF) secondary to an AVF occurs when the large amount of blood shunted through the access chronically increases venous return and ultimately exceeds the heart's compensatory capacity. Hemodialysis accesses usually consume about 20% of the cardiac output (CO), and AVF increases CO by 15% and end-diastolic ventricular pressure by 4% in most patients.⁸

HOCF is characterized by typical heart failure symptoms (dyspnea, orthopnea, peripheral or pulmonary edema, and reduced exercise tolerance), together with an elevated cardiac index and low systemic vascular resistance. Patients with pre-existing ischemic or valvular heart disease are particularly vulnerable, and symptoms often improve after flow reduction or obliteration of the access, underscoring the importance of a detailed history regarding the temporal relationship between access creation and symptom onset.

US reveals elevated venous flow volume and low-resistance arterial waveforms (Figure 5). The US should be used to determine the access volume flow (Qa) and the CO. An access flow > 2 L/min and a Qa:CO ratio > 25%⁸ are generally considered high and are associated with an increased risk of HOCF. Management focuses on reducing the hemodynamic burden on the heart while preserving dialysis access whenever possible. Surgical options include flow-reduction procedures such as RUDI, which typically decreases access flow by 50%,²³ banding techniques to create a controlled stenosis, and PAI. Ligation of the access is reserved for severe or refractory cases.

Aneurysm

An AVF aneurysm can be defined as a segmental dilatation of the arterialized

Table 3. US Criteria for Significant Stenosis (Practice Parameters and Technical Standards: ACR-AIUM-SRU Recommendations¹¹)

CRITERIA TYPE	VASCULAR ACCESS	THRESHOLD/VALUE
Morphological	- Luminal diameter reduction - Residual diameter (stenotic point) - Doppler spectral	≥50% reduction in transverse diameter compared with the uniform caliber segment upstream Diameter < 2-3 mm Parvus and tardus arterial waveforms are post-stenotic in the inflow artery
Hemodynamic	Peak systolic velocity ratio (anastomosis/artery 2 cm upstream) Absolute peak systolic velocity Peak systolic velocity ratio (narrowed draining vein/vein 2 cm caudally)	- Peak systolic velocity ratio (anastomosis/artery 2 cm upstream) > 3 may represent ≥50% stenosis within the anastomosis - Peak systolic velocity > 375 cm/s at the anastomosis or draining vein may represent ≥50% stenosis - Peak systolic velocity ratio (narrowed draining vein/vein 2 cm caudally) > 2:1 may represent ≥50% stenosis within the fistula
Functional (flow volume)	Arteriovenous fistula (inadequate flow)	Flow volume < 500 mL/min is predictive of access dysfunction

Table 4. Characteristic Locations and Clinical Relevance of Stenosis in Vascular Access

LOCATION	CLINICAL RELEVANCE
Juxta-anastomotic stenosis	The most common stenosis in native arteriovenous fistulas, affecting the first 2 cm of the draining vein immediately downstream of the anastomosis. It accounts for approximately 80% of all venous stenoses and is a frequent cause of early access failure. ³
Arterial inflow stenosis	Occurs proximal to the anastomosis and is present in up to 40% of dysfunctional arteriovenous fistulas. Etiologies include anastomotic narrowing from neointimal hyperplasia, technical surgical factors, or atherosclerotic disease in the feeding artery, the latter being more prevalent in elderly patients. ¹¹
Cannulation segment stenosis	A late complication typically resulting from the venous wall's fibrotic response to repeated needle trauma.
Central venous stenosis	Involves the central veins (eg, subclavian, brachiocephalic). Clinically, marked ipsilateral arm swelling often with a history of previous central venous catheterization.

vein involving all 3 wall layers, with a minimum diameter ≥18 mm, which corresponds to approximately a 3-fold enlargement of the recommended 6 mm diameter of a mature, usable fistula.²⁴ Its development is multifactorial and relates to degenerative changes triggered by repeated cannulation of

the same sites, recurrent endovascular dilatation of stenoses, and chronic hemodynamic stress.

Clinically, aneurysms present as localized, pulsatile, “ballooned” segments; they may progress to skin thinning, ulceration, infection, thrombosis, inability to puncture, or rupture with potentially

life-threatening hemorrhage.⁸ For this reason, the aneurysmal segment should be inspected at every dialysis session, with particular attention to rapid growth, shiny or translucent skin, necrotic patches, or bleeding; stable aneurysms without worrisome features can be monitored conservatively.

Duplex US is invaluable for assessing wall integrity and the extent of aneurysmal change. On B-mode imaging, the lesion appears as a fusiform or saccular venous dilation, sometimes partially filled by mural thrombus that may mask its true size angiographically. Color Doppler typically demonstrates slow, swirling flow within the cavity, generating the characteristic “Korean flag” or “yin-yang” appearance (Figure 6).³ True aneurysms may be associated with hemodynamically significant stenosis.⁸ When the overlying skin is compromised—thinned, ulcerated, or bleeding—surgical treatment is indicated.⁹

Pseudoaneurysm

A pseudoaneurysm (PSA) is a post-traumatic, perivascular blood collection that, unlike a true aneurysm, does not involve all 3 layers of the vessel wall. It has no true wall of its own; instead, it communicates with the parent vessel through a narrow neck and is contained

Figure 4. Hemodynamic characterization of steal syndrome in a brachiocephalic arteriovenous fistula. A 48-year-old man presented with pain, paresthesia, and numbness in the hand ipsilateral to a brachiocephalic arteriovenous fistula, associated with cyanosis and digital ulceration. Doppler US demonstrates bidirectional flow in the radial artery and reversed diastolic flow in the ulnar artery distal to the anastomosis. Manual compression of the arteriovenous fistula restores normal antegrade ulnar arterial flow and waveform morphology, confirming the diagnosis of hemodynamic steal syndrome.

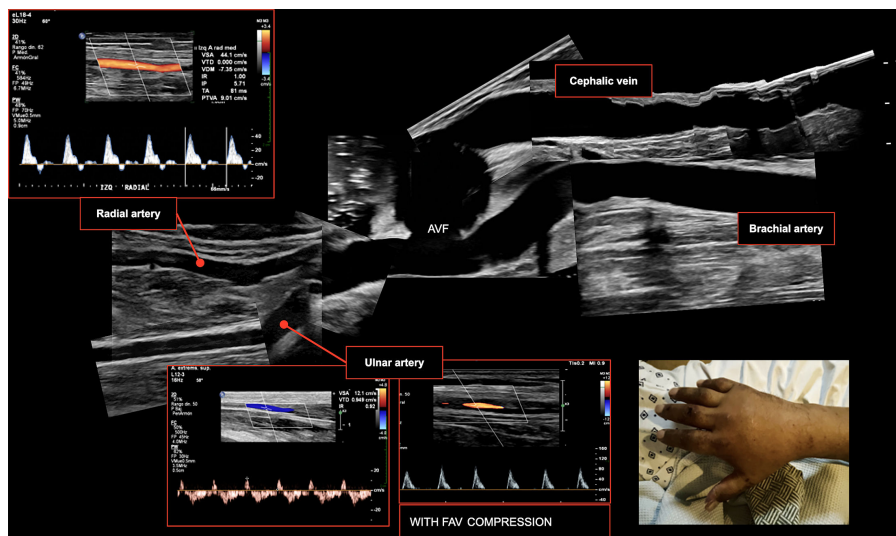
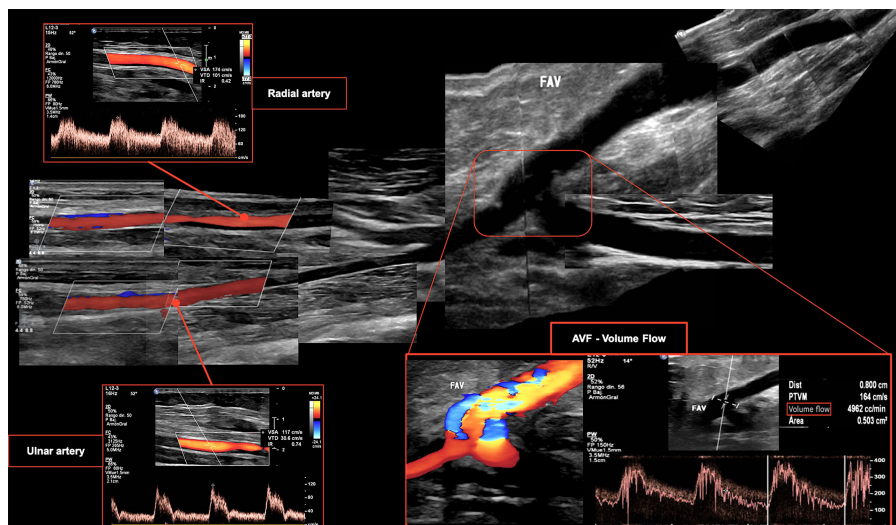


Figure 5. High-flow brachiocephalic arteriovenous fistula in a patient with dyspnea and edema, suggestive of high-output heart failure. A 50-year-old man with a left brachiocephalic arteriovenous fistula presented with generalized edema predominantly involving the left upper extremity and associated dyspnea. Quantitative Doppler assessment demonstrated markedly elevated access flow (4.9 L/min). Spectral analysis of the distal radial and ulnar arteries showed monophasic, low-resistance waveforms with loss of the normal triphasic pattern, consistent with substantial flow diversion into the fistula, reduced distal arterial perfusion, and a high-flow state predisposing to high-output cardiac failure.



by reactive fibrous tissue, which explains its higher risk of rupture compared with a true aneurysm of similar size. In the hemodialysis setting, PSAs occur most commonly in synthetic grafts and are usually related to cannulation mishaps,

repeated puncture of the same site, or extravasation after needle removal. Their formation typically requires a defect in the graft material combined with elevated venous pressure, often resulting from associated outflow stenosis. They may

involve the prosthesis, draining vein, or—less frequently—the feeding artery; anastomotic PSAs almost always warrant surgical repair.

Clinically, PSAs present as a pulsatile mass, and the overlying skin must be carefully inspected for thinning, scarring, ulceration, or spontaneous bleeding. Because of the high rupture risk, most require intervention, particularly when the sac exceeds twice the diameter of the adjacent graft or is larger than 1 cm with mural thrombus.

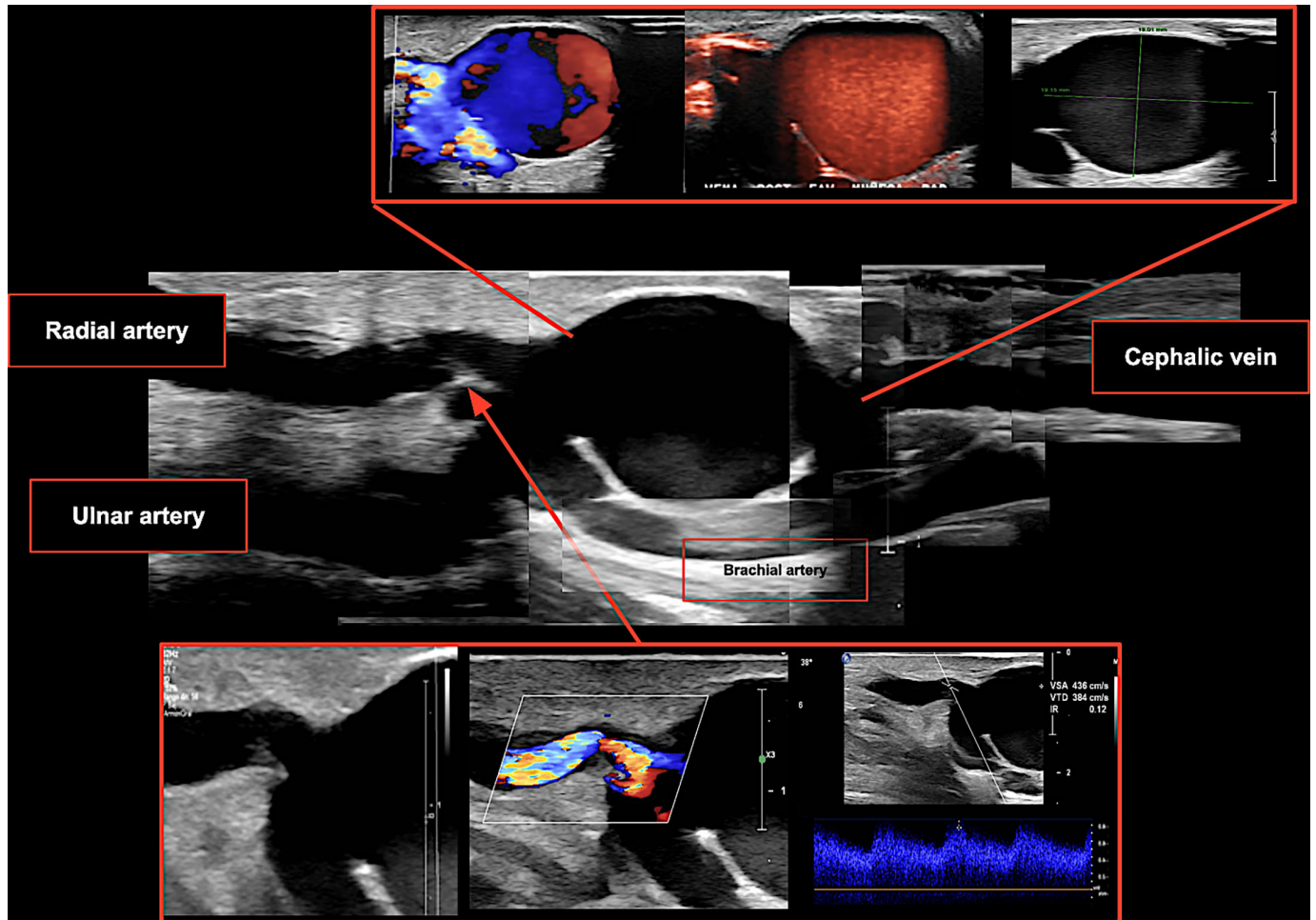
Duplex US is the first-line imaging modality and shows a perivascular anechoic collection with or without thrombus on B-mode. Color Doppler demonstrates swirling “yin-yang” flow within the sac, while spectral Doppler at the neck reveals the classic bidirectional “to-and-fro” pattern, sometimes with aliasing (Figure 7).³ Treatment options range from minimally invasive approaches—such as US-guided compression, percutaneous thrombin injection, or covered stent placement in selected graft lesions—to open surgical repair with resection and interposition graft.³

Hemorrhage

Hemorrhage is a rare but life-threatening complication, most often resulting from the rupture of a degenerated true aneurysm or a PSA, or from cannulation-related trauma.²⁵ The integrity of the overlying skin is critical: marked thinning with a shiny or translucent appearance, ulceration or necrotic patches, and any episode of spontaneous bleeding mandate urgent surgical evaluation.

Patients may present with external bleeding, expanding hematomas, or hypovolemic shock. On US, hemorrhage appears as heterogeneous perivascular collections with variable echogenicity depending on clot age. Color Doppler may demonstrate active extravasation of flow, which is diagnostic (Figure 8). When rupture risk is high or bleeding is ongoing, temporary endovascular stent graft placement may be considered as a bridge to definitive surgery, while in

Figure 6. True aneurysm in a brachiocephalic arteriovenous fistula with proximal radial artery stenosis. A 27-year-old woman with a right brachiocephalic arteriovenous fistula presented with progressive right upper extremity edema and difficult cannulation during hemodialysis. Grayscale and color Doppler US show a true aneurysm of the vein measuring 18.01×19.15 mm. Immediately distal to the aneurysm, the radial artery demonstrates a focal, high-grade stenosis with marked luminal narrowing, color aliasing, and elevated peak systolic velocities on spectral Doppler, consistent with flow-limiting stenosis and aneurysmal degeneration.



extreme cases, access ligation may be required, at the cost of losing the access.⁸

Infection

Infection of AVFs contributes substantially to morbidity, accounting for a significant proportion of access-related complications and predisposition to aneurysm, PSA, and hemorrhage through progressive vessel wall damage. Risk factors include poor patient hygiene, diabetes, older age, and history of bacteremia.²⁶

Staphylococcus aureus is the predominant pathogen, followed by *Staphylococcus epidermidis*. Most AVF infections are localized to the puncture sites and

present as perivascular cellulitis with erythema, swelling, and tenderness, but patients may also develop systemic manifestations such as fever, chills, or rigors, and deep infection or abscess formation should be suspected in cases involving fluctuance, purulent drainage, or compromised skin integrity. Because access infection can serve as a nidus for bacteremia and endocarditis, blood and local cultures are mandatory when infection is suspected. Transthoracic echocardiography is recommended in cases of *S. aureus* bacteremia to rule out septic emboli.

US demonstrates vessel wall thickening, perivascular edema, heterogeneous

periaccess collections, and hyperemia on color Doppler (Figure 9). The ability to identify abscesses is particularly useful for guiding drainage and monitoring treatment response. Surgical revision or excision is indicated when medical therapy fails, there is perivascular abscess requiring drainage, or the fistula becomes a source of recurrent septic emboli.²⁷

Venous Hypertension

Venous hypertension is a painful, nonthrombotic complication of AVFs caused by impaired venous outflow, most commonly resulting from stenosis. The condition presents with arm swelling, varicosities, pain, and ulceration. The

Figure 7. Multiple pseudoaneurysms in the draining vein of a left brachiocephalic arteriovenous fistula. A 31-year-old woman with a left brachiocephalic fistula and episodes of absent venous flow during hemodialysis was evaluated with US. Grayscale imaging demonstrates 3 sac-like dilatations along the draining vein, compatible with pseudoaneurysms, likely related to repeated cannulation, with preservation of fistula patency. Within the sacs, intraluminal echogenicity and circular swirling of blood are evident, reflecting marked flow deceleration. Color Doppler shows recirculating flow with a characteristic “yin-yang” appearance, while spectral Doppler at the pseudoaneurym neck demonstrates a classic “to-and-fro” (bidirectional) waveform.

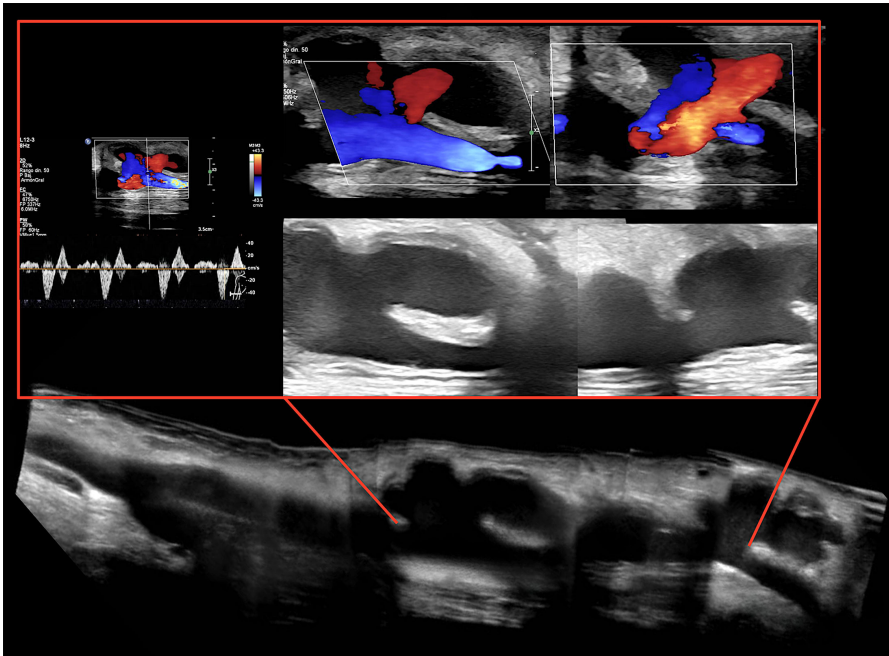
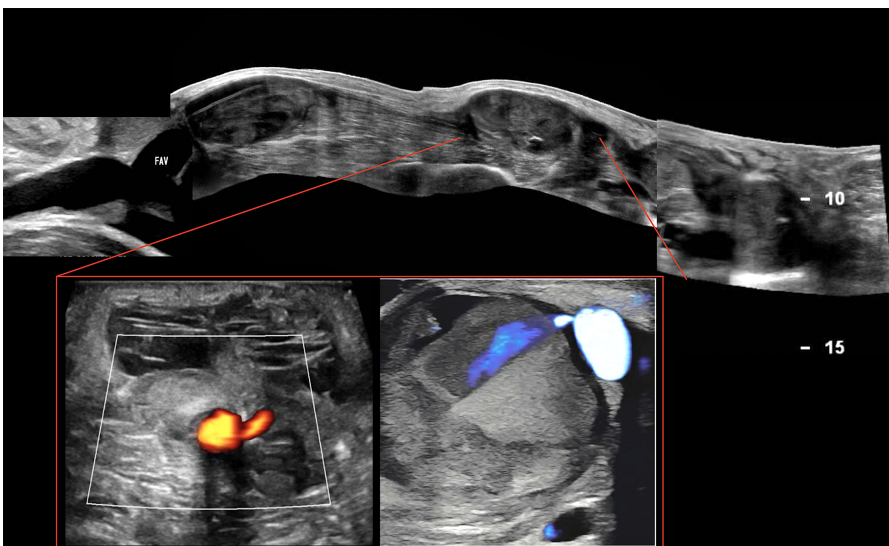


Figure 8. Acute hemorrhage from a radiocephalic arteriovenous fistula. A 39-year-old man with chronic kidney disease and a right radiocephalic arteriovenous fistula presented with rapidly progressive swelling and erythema of the ipsilateral upper extremity. Panoramic grayscale US shows an extensive heterogeneous hematoma along the draining vein. In the mid-third of the vein, color Doppler demonstrates a focal high-velocity jet breaching the fistula wall into the surrounding collection, indicating active extravasation.



most advanced stages of this complication can progress to marked discoloration of the affected limb and, in extreme cases, culminate in venous gangrene. Given its often insidious onset and potential misattribution to other causes of edema, this entity is likely under-recognized and under-reported.

US findings include venous dilatation, turbulent or reversed flow, and evidence of collateral circulation (Figure 10). Recognition is important, as untreated venous hypertension leads to progressive morbidity and functional impairment.

Management is primarily surgical, with selective ligation of the arterialized veins draining into the hand. When the deep venous system is arterialized, fistula closure is required. Only mild cases, usually limited to edema, can be managed conservatively with limb elevation and compression bandaging.²⁸

Conclusion

US has established itself as the first-line modality for AVF evaluation in patients undergoing hemodialysis. Its capacity to provide detailed anatomical and hemodynamic information makes it indispensable in routine surveillance and emergency settings. This review underscores the characteristic findings of the most common and uncommon complications. For radiologists, familiarity with these entities and adherence to standardized protocols are essential to ensure reproducibility and reduce interoperator variability.

Future developments, including the integration of advanced techniques such as contrast-enhanced US and elastography, may provide additional insights into vascular wall properties and flow dynamics. Artificial intelligence also holds promise for automating vessel segmentation and objectively quantifying flow, potentially reducing operator dependence.

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