Vascular Access for Dialysis: Types, Complications, and Management

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July 2026

Overview: Access Types & Hierarchy

Goal of vascular access: Provide **fast, reliable blood flow (>200 mL/min)** for hemodialysis

Hierarchy (Fistula First Initiative): 1. **Arteriovenous Fistula (AVF)** — Gold standard 2. **Arteriovenous Graft (AVG)** — Bridge option 3. **Central Venous Catheter (CVC)** — Last resort; temporary

> [!important] Key Point **Fistula First Initiative mandate**: Nephrologists must attempt AVF in all suitable patients before considering AVG/CVC. AVF superiority in patency, infection rates, and survival well-established.

I. ARTERIOVENOUS FISTULA (AVF) — Gold Standard

Anatomy & Physiology

AVF = Surgical **anastomosis of artery to vein** (bypassing capillaries) - Shunts blood directly from artery → vein - Results in **arterialization of vein** (thick, muscular, pulsatile) - **Flow rates**: 400-1000+ mL/min (highest of all access types)

Advantages: - **Longest survival**: Mean 5+ years (vs. 3-5 years for AVG, <1 year for CVC) - **Best patency**: 50-60% primary patency at 5 years - **Lowest infection rate**: <1% per year (vs. 10-20% for CVC) - **Lowest cost**: One surgical procedure; minimal maintenance - **Superior outcomes**: ↓ mortality, ↓ hospitalization vs. other access types

Types of AVF by Location

Fistula	Vessels	Site	Maturation Time	Success Rate	Comments
Radiocephalic	Radial artery → cephalic vein	Wrist (forearm)	8-12 weeks	50-70%	First choice; smallest vessels; slowest to mature
Brachiocephalic	Brachial artery → cephalic vein	Elbow	6-8 weeks	80-90%	Larger vessels; faster maturation
Brachiobasilic	Brachial artery → basilic vein	Elbow/upper arm	8-12 weeks	85-95%	Highest success; requires vein transposition
Thigh graft (AAV)	Femoral artery → femoral vein	Thigh	Variable	60-70%	Reserved if arm access exhausted

> [!tip] Clinical Pearl **Non-dominant arm preferred**: Preserves dominant hand function. However, non-dominant arm vessels often smaller. Intraoperative duplex often needed to assess vessel adequacy.

"Rule of 6s" for AVF Maturation

If AVF meets these criteria, likely to mature successfully: - ≥**6 mm vein diameter** (usually cephalic at wrist) - ≥**2 mm artery diameter** (radial or brachial) - ≥**6 weeks maturation** before use (sometimes up to 12 weeks needed) - **Goal**: 6 mm vein, 6 mm artery, 6 weeks maturation = 60% mature fistula

> [!important] Key Point **AVF maturation timeline**: Nephrologists often delay dialysis initiation to allow 8-12 weeks maturation. This is appropriate; premature AVF cannulation → thrombosis. Educate patients: mature fistula takes time; patience essential.

Cannulation Technique

Buttonhole cannulation (preferred now): - Same two needle sites used repeatedly - Creates scar tunnel (buttonhole) - Reduces vein aneurysm formation, patient pain - Requires trained staff; risk of infection if technique poor

Rope ladder (standard) (older method): - Multiple needle insertion sites rotated along access length - Prevents aneurysm at single site - More vein traumatization if <2-3 weeks between same site reuse

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II. ARTERIOVENOUS GRAFT (AVG) — Bridge Option

Anatomy & Physiology

AVG = Surgical **anastomosis of artery to vein via synthetic conduit** - Graft material: PTFE (polytetrafluoroethylene), polyurethane - Permits immediate/rapid cannulation (2-4 weeks vs. 8-12 for AVF) - **Flow rates**: 200-600 mL/min (adequate but less than AVF)

Advantages: - **Faster maturation**: 2-4 weeks to cannulation (vs. 8-12 weeks AVF) - **Larger vessels not required**: Works even with small vessels - **Bridge while awaiting AVF maturation**: Provides access during wait

Disadvantages: - **Shorter survival**: Mean 3-5 years patency (vs. 5+ AVF) - **Higher infection rate**: 5-10% per year (vs. <1% AVF) - **Thrombosis common**: ~50% thrombose by 2-3 years; needs surveillance/intervention - **Higher cost**: Multiple interventions often needed - **Pseudoaneurysms common**: Graft material weakens with needle puncture trauma

Graft Configuration

Configuration	Vessels	Site	Notes
Loop graft	Brachial artery → basilic vein (curved path)	Upper arm	Optimal; excellent flow
Straight graft	Radial artery → cephalic vein	Forearm	Lower maturation
Thigh graft	Femoral artery → femoral vein	Thigh	Last resort; infection risk ↑

III. CENTRAL VENOUS CATHETER (CVC) — Temporary

Types of CVC

Temporary (non-tunneled): - **Subclavian CVC**: Immediate access; risk of subclavian steal, ↑ stenosis - **Jugular CVC**: Preferred temporary; lower stenosis risk than subclavian - **Femoral CVC**: Reserved for emergency; highest infection risk - **Placement site**: Bedside (preferably via ultrasound) - **Duration**: Hours to days (high infection risk after 1-2 weeks)

Semi-permanent (tunneled): - **Hickman, Groshong catheters**: Tunneled under skin; Dacron cuff reduces infection - **Duration**: Weeks to months acceptable - **Approval**: FDA-approved for palliative/short-term use

Permanent (tunneled): - **Permacath, Tesio**: Tunneled; double-lumen; implanted surgically - **Duration**: Months to years if needed - **Use case**: When AVF/AVG not feasible or failed

CVC Characteristics

Advantages: - **Immediate access**: Usable same day - **No surgery**: Insertion by interventional radiology/nephrology - **Works with any vessel size**: No vessel size requirements - **Multiple sites possible**: Neck, chest, leg

Disadvantages: - **Highest infection rate**: 10-20% per year; **bloodstream infections, sepsis** - **Shortest survival**: Mean <1 year; many need replacement - **Catheter dysfunction common**: Fibrin sheaths, malposition - **Superior vein stenosis**: ↑ incidence of central vein stenosis (can limit future AVF in that arm) - **High cost**: Frequent replacements - **Highest mortality**: CVCs associated with worst outcomes in dialysis patients

> [!warning] High-Yield Board Point **Mortality with CVC**: HD patients with CVCs have 30-50% higher mortality than AVF patients in first year. CVC best reserved for true temporary access (acute renal failure expected to recover).

Complications & Management

ARTERIOVENOUS FISTULA COMPLICATIONS

Steal Syndrome (Vascular Insufficiency) **Mechanism**: Fistula diverts blood away from distal limb → ischemia

Incidence: 1-5% (more common with brachial artery AVF)

Presentation: - **Acute**: Pain, numbness, coldness, pallor distal to AVF - **Chronic**: Slow progression over weeks; claudication with use; ischemic pain; ulceration; gangrene (rare) - **Ischemic monomelic neuropathy (IMN)**: Nerve ischemia despite adequate hand perfusion (painful swelling)

Risk factors: - Brachial artery AVF (especially elbow) - Female, diabetic, peripheral artery disease - Small distal vessel diameter (<2.5 mm)

Diagnosis: - **Clinical**: Hand claudication, coolness, pain with fistula use - **Doppler ultrasound**: ↓ Distal artery flow; steal flow calculation - **ANGIO**: Angiography if considering intervention

Management: - **Mild symptoms**: Conservative (exercise, fistula ligation only if severe) - **Banding**: Narrow fistula to ↓ flow (maintains access, reduces steal) - **DRIL (Distal Revascularization Interval Ligation)**: Bypass distal artery + ligate proximal; better outcomes - **Ligation**: Last resort if access no longer needed or intolerable symptoms

> [!tip] Clinical Pearl **Steal syndrome prediction**: Brachial artery AVF diameter >7

mm + flow >1000 mL/min = high steal risk. Consider banding prophylactically if symptomatic.

Aneurysm & Pseudoaneurysm **True aneurysm**: Dilated vein at fistula site from hemodynamic stress

Pseudoaneurysm (false aneurysm): Cannulation-related; graft material rupture containing clot

Presentation: Bulge at fistula site, pain, risk of rupture/bleeding

Management: - Buttonhole cannulation reduces true aneurysm formation - Pseudoaneurysm: Often requires graft revision/replacement - True aneurysm: Usually conservative unless large (>3 cm) or symptomatic → surgical intervention

Thrombosis **Incidence**: 5-10% in early AVF period; lower long-term

Mechanism: Low flow state (inadequate fistula maturation, stenosis)

Presentation: Loss of thrill/bruit; inability to cannulate

Management: - **Early**: Thrombectomy ± angioplasty (if caught <24 hours) - **Late**: Intervention often fails; may need new access

Stenosis (Venous, Arterial) **Venous stenosis**: Most common; narrowing at fistula anastomosis or downstream

Incidence: 30-40% at 1 year; may not require intervention if flow adequate

Diagnosis: ↑ venous pressure, ↑ recirculation rate, duplex ultrasound

Management: - **Surveillance**: Monitor K+ recirculation, pressure ratio - **PTA (percutaneous transluminal angioplasty)**: If stenosis >50% + hemodynamically significant - **Repeat interventions**: High restenosis rate (~50% at 6 months)

Infection **Rare in native AVF** (<1% per year) unless arteritis or hematogenous seeding

Management: Broad-spectrum antibiotics; ligation if septic/endocarditis

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ARTERIOVENOUS GRAFT COMPLICATIONS

Thrombosis **Most common complication**: ~50% of grafts thrombose by 3 years

Risk factors: Stenosis, low flow, hypercoagulability

Management: - **Declot procedure**: Mechanical or pharmacologic thrombolysis ± angioplasty - **Success rate**: 80-90% declot success; but re-thrombosis common - **Cumulative burden**: Repeated declots worsen long-term graft outcomes

Pseudoaneurysm **More common in grafts than fistulas** (graft material weakness)

Presentation: Pulsatile bulge, risk of rupture

Management: Graft segment revision or replacement

Infection **Higher risk than AVF**: 5-10% per year

Presentation: Erythema, warmth, purulent drainage

Diagnosis: Blood cultures, ultrasound, imaging

Management: - **Localized**: Antibiotics + possible percutaneous drainage - **Systemic sepsis**: Graft removal + antibiotic therapy

Stenosis (Venous) **Common**: 30-50% develop stenosis

Management: PTA as for AVF

CENTRAL VENOUS CATHETER COMPLICATIONS

Bloodstream Infection (CLABSI) **Highest infection rate of all access types** (10-20% per year)

Causative organisms: *Staphylococcus aureus* (most common), *Staphylococcus epidermidis*, *Candida*, gram-negatives

Prevention: - Aseptic technique during insertion - Sterile dressing changes - Catheter cap changes with each treatment - Minimize catheter dwell time

Management: - **Non-tunneled CVC**: Usually remove + treat antibiotics - **Tunneled CVC**: Attempt antibiotics $\pm$ lock therapy (vancomycin/heparin); remove if persistent infection

Catheter Dysfunction **Causes**: Fibrin sheath, malposition, thrombus, tip migration

Diagnosis: $\downarrow$ flow rates, $\uparrow$ venous pressures, imaging confirmation

Management: - **Repositioning**: Guidewire manipulation - **TPA (tissue plasminogen activator)**: Fibrin lysis - **Replacement**: If not salvageable

Central Vein Stenosis/Thrombosis **Risk higher with subclavian CVC** than jugular

Presentation: Arm swelling, $\uparrow$ venous pressures in ipsilateral AVF

Prevention: Prefer jugular > femoral > subclavian placement

Management: - PTA for symptomatic stenosis - May compromise future AVF in that arm (surgical concern)

Timing & Pathway to Dialysis

Coordinated Care Approach

GFR Stage	Action	Rationale
GFR 15-20	Refer to vascular surgery for AVF planning	Allows 8-12 week maturation
GFR 15	Create AVF if feasible	Need time before ESRD
GFR 5-10	Educate re: modality; assess fistula maturation	Prepare for RRT
GFR <5	Start dialysis if AVF mature; else CVC as bridge	Don't delay if urgent start needed
Emergent start	CVC acceptable; plan AVF while on HD	Transition to AVF once mature

"Fistula First" Bundle

1. **Early nephrology referral** (GFR <20)
2. **Vascular mapping** (duplex ultrasound) before surgery
3. **Attempted AVF** in all suitable candidates (age <75, suitable vessels)
4. **Patient education** on importance of fistula care/maturation
5. **Monitoring** for maturation + early intervention if problems

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Clinical Pearls & Pitfalls

[!tip] Clinical Pearl **Fistula maturation failure**: 20-30% of AVF never mature. Factors: Small starting vessel size, female, diabetes, poor compliance. Vascular duplex before surgery improves success (cephalic vein >3 mm, artery >2.5 mm = 80% success).

[!warning] High-Yield Board Point **Subclavian steal with CVC**: CVC in subclavian vein → thrombosis → collateral development → reversal of flow in ipsilateral arm → hand ischemia. Prefer jugular > femoral > subclavian.

[!important] Key Point **Surveillance prevents thrombosis**: Monitoring AVF/AVG with measurement of venous pressure ratios, recirculation, physical exam (thrill/bruit) allows detection of stenosis BEFORE thrombosis. Early PTA restores access.

[!tip] Clinical Pearl **CVC lifespan**: Non-tunneled CVC safe <3 weeks; semi-tunneled weeks-months; only long-term tunneled catheter acceptable. Plan for permanent access while using CVC.

[!warning] High-Yield Board Point **Brachiobasilic fistula superior**: Requires vein transposition (two-stage procedure) but highest success rate (85-95%) and best long-term outcomes. Consider if cephalic vein inadequate.

Related Resources

- Dialysis Kinetics & Adequacy
- CKD Comprehensive Management Pathways
- Dialysis Initiation & Modality Review

Last reviewed: 2026-02-28 | **Next update due:** 2026-08-28