Dialysis Access and Complications: Student Handout

Andrew Bland, MD, FACP, FAAP

March 2026

Dialysis Access and Complications: PA/Medical Student Handout

Learning Objectives

By the end of this module, students will be able to:

1. Assess vascular access for functionality (bruit, thrill, flow adequacy)
2. Identify common vascular access complications and distinguish between them
3. Understand PICC line contraindications and permanent vascular damage they cause
4. Describe evidence-based antibiotic dosing adjustments for dialysis patients
5. Recognize and manage catheter-related infections
6. Apply pharmacokinetic principles to extended-interval dosing strategies

---

Section 1: Vascular Access Assessment

Clinical Examination Techniques

Bruit (Auditory Assessment) **Definition:** Whooshing sound created by turbulent flow through access

Technique: 1. Place stethoscope diaphragm directly over access 2. Listen for continuous "to-and-fro" sound 3. Normal finding indicates adequate flow

Absence of bruit suggests: - Access clotting - Severe stenosis - Low flow state

Clinical Pearl: All functioning accesses should have an audible bruit. Absence is a RED FLAG for access dysfunction.

Thrill (Palpatory Assessment) **Definition:** Vibration palpable over access from turbulent flow

Technique: 1. Place fingertips over access segment 2. Feel for continuous vibration synchronous with pulse 3. Should extend entire length of accessible access

Absence of thrill indicates: - Access clotting - Severe stenosis - Insufficient flow

Clinical Pearl: Loss of thrill is an earlier sign of stenosis than loss of bruit. Serial assessment helps detect deterioration.

Flow Assessment **Qualitative:** Observe needle cannulation and blood drawing - Brisk flow = adequate (>500-600 mL/min typical) - Sluggish flow = concerning (may indicate stenosis or poor needle placement) - Difficulty drawing blood = access malfunction until proven otherwise

Quantitative: Access flow studies (ultrasound dilution or thermal dilution) - Normal fistula flow: 800-1200+ mL/min - Normal graft flow: 600-1000 mL/min - Catheter: 300-400+ mL/min (dependent on lumen size) - Inadequate: <500 mL/min signals need for intervention

---

Section 2: Vascular Access Types

Arteriovenous Fistula: The Gold Standard

Surgical Anatomy: - Direct connection between artery and vein (no synthetic material) - Most commonly: radial artery to cephalic vein (forearm) - Alternative: brachial artery to basilic vein (upper arm) - Requires surgical creation under local or general anesthesia

Maturation Process:

Timeline	Changes	Readiness
Week 1-2	Acute dilation begins; no cannulation	Not ready
Week 3-4	Progressive dilation; vein thickens	Approaching readiness
Week 6-8	Stabilization; adequate size/thickness	Ready for cannulation
Week 8-12	Optimal for most patients	Preferred cannulation window

Why 6-8 weeks required: Vein must develop sufficient diameter (>4-5 mm) and wall thickness to withstand needle punctures and maintain hemostasis.

Advantages: - Longest survival (10-15+ years possible) - Lowest infection rates - Highest achievable blood flow rates (400-600+ mL/min) - Avoidance of synthetic material

Disadvantages: - Cannot use immediately (wait required) - Requires advance planning before ESRD - Risk of steal syndrome with distal ischemia - Cardiac effects from high flow (right heart strain) - Requires adequate native vessels (rules out patients with prior dialysis catheter damage)

Complications:

Complication	Mechanism	Management
Steal syndrome	Excessive flow diverts distal blood	Access ligation or revision; distal revascularization
Aneurysm	Repeated needle trauma; vein wall weakening	Surgical repair if symptomatic or expanding
Stenosis	Intimal hyperplasia at arterial or venous anastomosis	Angioplasty; surgical revision if severe

Complication	Mechanism	Management
Thrombosis	Clot formation in fistula	Thrombectomy; re-evaluation for cause

Arteriovenous Graft: Bridge Solution

Composition: Synthetic conduit (usually PTFE - polytetrafluoroethylene) connecting artery to vein

Advantages: - Faster maturation (2-4 weeks) - Can be used sooner than fistula - Option when native vessels inadequate

Disadvantages: - Higher infection rates than fistula (synthetic material provides bacterial nidus) - Higher thrombosis risk (stenosis develops more readily) - Shorter lifespan (typically 3-5 years vs. 10+ for fistulas) - Cannot place if previous PICC or central catheter damage present

Complications:

Complication	Incidence	Characteristic
Infection	10-20% annually	Higher than fistula; often requires graft removal
Thrombosis	20-30% annually	Often preceded by stenosis
Stenosis	Common	Usually at venous anastomosis
Pseudoaneurysm	Less common than fistula	Risk of rupture; requires repair

Central Venous Catheter (CVC): Temporary Solution

Placement: Tunneled catheter, usually internal jugular vein (IJ) - Dual-lumen design allows simultaneous blood withdrawal and return - Subcutaneous tunnel reduces infection risk vs. non-tunneled catheters

Indications: - Acute dialysis initiation - Permanent access failure or maturation delay - Temporary use while fistula/graft matures - Patients without vascular access options

Advantages: - Immediate access (can use at insertion) - No vascular anatomy requirements - Suitable for acute situations

Disadvantages: - Highest infection rates (2.1 per 1000 catheter-days) - Risk of central venous stenosis/thrombosis - Mechanical dysfunction (kinks, clots) - Limitation to blood flow (~300-400 mL/min typical)

Complications:

Complication	Incidence	Prevention
Catheter-related bloodstream infection (CRBSI)	Most common	Aseptic technique; antibiotic lock therapy

Complication	Incidence	Prevention
Central venous stenosis	10-50% (varies with studies)	Avoid subclavian; prefer IJ; limit dwell time
Thrombosis	5-10%	Anticoagulation; regular flushing
Mechanical dysfunction	Common	Proper fixation; avoid kinks
Arrhythmias	Rare	From catheter malposition near SA node

Clinical Pearl: Limit catheter use to temporary situations when possible. Each day of catheter use increases infection risk and damages future access options.

Section 3: Devastating Impact of PICC Lines in Dialysis Patients

The PICC Line Problem: A Cautionary Tale

PICC Line Definition: Peripherally inserted central catheter; placed through peripheral vein (usually basilic or cephalic), advanced to central circulation

Vascular Damage Statistics

Central Venous Stenosis/Thrombosis: - Post-PICC stenosis: 7% of dialysis patients - Central and peripheral vein abnormalities: 7.5% overall - Pre-post venography: 4.8% develop central stenosis; 2.7% complete central occlusion

Thrombosis Incidence (Most Damaging): - Overall venographic detection: 23-57% in dialysis patients - By site: - **Cephalic vein:** 57% thrombosis (destroys best fistula vein!) - **Basilic vein:** 14% thrombosis (alternative fistula vein) - **Brachial vein:** 10% thrombosis

Hazard Ratios for Upper Extremity Deep Vein Thrombosis: - PICC recipients: 10-fold increased hazard (HR 10.49, 95% CI 5.23-21.04) - Overall VTE risk: 3-fold increase

Impact on Dialysis Access Creation

The Catastrophic Problem: Damaged vessels cannot support arteriovenous fistula

Evidence: - Prior PICC use: 3-fold lower odds of functioning AVF (OR 3.2, 95% CI 1.8-5.7) - Case-control analysis: 44% without functioning AVF had prior PICC vs. only 20% with successful AVF

Why This Matters: Damaged vessels mean: - Failed fistula creation attempts - Forced dependence on AVG or catheter - Chronic infection risk - Repeated access procedures and surgeries - Permanent compromise of future options

Professional Guidelines

All major organizations strongly discourage PICC placement:

KDOQI 2019 Update: > "In patients with chronic kidney disease stage 4 or 5, forearm and upper-arm veins suitable for placement of vascular access should NOT be used for venipuncture or placement of PICC lines." (Grade B Recommendation)

Rationale: Preserves "ESKD Life-Plan" - comprehensive care ensuring available dialysis options throughout life

American Academy of Family Physicians - Choosing Wisely: > "Don't place central lines or PICCs in pediatric patients with advanced CKD without nephrology consultation"

Goal: Avoid adverse events, preserve long-term access, prevent unnecessary costly procedures

Society of Interventional Radiology & Infectious Diseases Society of America: - Recommend tunneled catheters over PICCs for central access >3 weeks duration - Explicitly note thrombosis risks

Clinical Pearl

There is NO good reason to place PICC in a dialysis patient. Superior alternatives exist that don't damage future access options.

Section 4: Superior Alternatives to PICC Lines

Strategy 1: Use Existing Dialysis Access

Optimal approach for patients with functioning fistula or graft: - Administer antibiotics during scheduled dialysis sessions - No additional catheter required - Eliminates infection risk from additional access - Preserves all veins for future options - Improves quality of life (no daily hospital visits or home infusion setup)

Works best with: - Extended-interval antibiotics (daptomycin, ceftriaxone) - 3x/week dosing aligned with dialysis schedule - Thrice-weekly post-dialysis dosing

Strategy 2: Small-Bore Tunneled Internal Jugular Catheter

Design: 4-6 French tunneled catheter (much smaller than dialysis catheters)

Advantages over PICC: - Longer functional duration (weeks to months vs. days to weeks) - Avoids peripheral and subclavian veins (preserves forearm/upper arm vessels) - Compatible with antibiotic lock therapy - Minimal vascular trauma - No evidence of symptomatic central venous thrombosis when placed via IJ approach

Disadvantages: - Requires separate procedure for placement - Daily access increases infection risk vs. dialysis-integrated approach - Not suitable for long-term (months) use

Technical advantage: IJ placement superior to subclavian (which causes 42% stenosis rate)

Strategy 3: Antibiotic Lock Therapy

Concept: High-concentration antibiotic solution instilled into catheter lumen between uses

Standard Preparations: - Vancomycin 5 mg/mL OR ceftazidime 10 mg/mL - Combined with heparin (anticoagulation) - Dwell throughout interdialytic period

Efficacy: - Eradicates biofilms within catheter - Catheter salvage rate: 50-67% - Prevents catheter-related infections

Mechanism: Achieves antibiotic concentrations 100-fold higher than systemic levels

---

Section 5: Pharmacokinetic Principles for Dialysis Patients

Why Standard Dosing Fails

Problem: Drugs eliminated by kidney function and dialysis in ways that differ from patients with normal renal function

Key Principle: Dialysis REMOVES some drugs but not others: - **Highly protein-bound drugs:** Not dialyzable (>90% bound) - **Large molecular weight drugs:** Not removed by standard dialysis - **Small, water-soluble drugs:** Removed efficiently by all dialysis modalities - **Middle-molecular-weight drugs:** Partially removed; more with high-flux or HDF

Daptomycin Pharmacokinetics in ESRD

Normal renal function: - Half-life: 8-9 hours - Clearance: Primarily renal - Protein binding: 90-95%

ESRD (Dialysis Patients): - Half-life: 28-52 hours (3-6x prolongation!) - Clearance: Minimal renal excretion; 90-95% protein binding protects from dialysis - **Clinical implication:** Can use extended-interval dosing (48-72 hours)

Pharmacokinetic Evidence: - Daptomycin 6-9 mg/kg every 48 hours achieves area-under-curve comparable to normal daily dosing - Monte Carlo simulations support thrice-weekly post-dialysis administration at 10-12 mg/kg - Clinical validation: Successful treatment of complex cases including vancomycin-resistant enterococcal prosthetic valve endocarditis

Dosing Strategy: 8-10 mg/kg every 48 hours OR 12 mg/kg every 72 hours post-dialysis

Ceftriaxone Pharmacokinetics in ESRD

Normal renal function: - Half-life: 6-8 hours - Elimination: Renal (33-67%) + hepatic biliary (33-67%) - Protein binding: 83-95%

ESRD (Dialysis Patients): - Half-life: 14-17 hours (2-3x prolongation) - Plasma clearance: Decreases to 529-705 mL/h - Dialytic removal: Only 41% over 4 hours (poorly dialyzable despite moderate protein binding) - **Result:** Drug accumulation with repeated dosing

Population Pharmacokinetic Evidence: - Three-times-weekly post-dialysis 2-gram dosing maintains unbound concentrations above 1 mg/L for organisms with MIC ≤1 mg/L (98% probability) - Compatible with extended interval strategies

Safety Concern - Neurotoxicity: - Threshold: Serum concentrations >100 μg/mL - Risk factors: Age >60, hypoalbuminemia, hepatic dysfunction, duration >7 days - Manifestations: Con-

fusion, myoclonus, seizures, choreoathetosis - Management: Discontinue; switch to alternative (meropenem, ciprofloxacin)

Clinical Pearl: Ceftriaxone neurotoxicity appears related to accumulation, not dose. Careful monitoring essential when extended-interval dosing used.

Extended-Interval Dosing Combinations

Daptomycin + Ceftriaxone (Standard Extended-Interval Regimen) Dosing: - Daptomycin: 8-10 mg/kg every 48 hours post-dialysis - Ceftriaxone: 2 grams three-times-weekly post-dialysis

Evidence: - Pharmacokinetic modeling supports bactericidal activity comparable to daily regimens - Clinical validation: Successful treatment of vancomycin-resistant enterococcal endocarditis - Practical advantage: Both given during dialysis; no additional catheter needed

Monitoring: - Daptomycin: Weekly CPK (risk of myopathy); target trough >24.3 mg/L - Ceftriaxone: Serial neurological exams; therapeutic drug monitoring if available (target <100 μg/mL)

Teicoplanin (European Alternative) Availability: Limited to Europe and Asia (not available in U.S.)

Pharmacokinetics: - Normal half-life: 50 hours - ESRD half-life: 83-182 hours (γ-phase elimination) - Protein binding: 90-95% - Dialytic clearance: Negligible

Dosing: - Loading: 6 mg/kg every 12 hours × 3 doses - Maintenance: 400-800 mg every 72 hours (every 3 days) - Alternative: 800 mg loading, then 400 mg on days 2, 3, 5, 12, 19

Advantages: Even more favorable extended-dosing pharmacokinetics than daptomycin

Evidence: 40-patient Italian cohort demonstrated excellent tolerance and efficacy

---

Section 6: Evidence-Based Antibiotic Therapy for Enterococcal Endocarditis in Dialysis Patients

Standard First-Line Therapy

Regimen: Ampicillin 2g every 4-6 hours + Ceftriaxone 2g every 12 hours × 6 weeks

Why This Combination? - Dual β-lactam approach superior to traditional gentamicin combinations - Landmark trial (Gavaldà, 43 patients): 67.4% clinical cure rate - Spanish multicenter trial: Equivalent efficacy to ampicillin-gentamicin with significantly less nephrotoxicity (0% vs. 23%, $p<0.001$) - Meta-analyses: Non-inferiority confirmed; reduced treatment discontinuation (OR 0.11, 95% CI 0.03-0.42)

Vascular Access for Standard Therapy: - Small-bore tunneled IJ catheter (4-6 French) - Allows daily infusions without peripheral vein damage - Requires 6 weeks of daily hospital/infusion visits OR complex home therapy setup

Limitations: - Ampicillin has substantial dialytic clearance (71%) and shorter ESRD half-life (17.4 hours) - Not suitable for 48-hour dosing intervals (subtherapeutic concentrations by hour 36) -

Ceftriaxone dose-dependent neurotoxicity at daily 2g dosing for 6 weeks - Daily catheter access increases cumulative infection risk

Extended-Interval Alternative for Selected Patients

Target Population: - Hemodynamically stable patients - Non-complicated native valve endocarditis (no perivalvular abscess, no prosthetic valve) - Prioritize quality of life and reduced healthcare utilization - Good adherence likelihood

Regimen: Daptomycin 8-10 mg/kg every 48 hours + Ceftriaxone 2g three-times-weekly (both post-dialysis)

Advantages: - Eliminates need for additional catheter (uses existing dialysis access) - Reduces healthcare resource utilization - Improves patient quality of life (no daily visits; no home infusion setup) - Reduces cumulative infection risk from daily catheter manipulation - Pharmacokinetically sound per modeling studies

Evidence: - Daptomycin pharmacokinetics in ESRD support 48-hour dosing - Cephalosporin dosing studies validate thrice-weekly post-dialysis administration - Clinical case reports document successful treatment of complex cases

Monitoring Requirements: 1. **Daily neurological assessment** (ceftriaxone neurotoxicity risk) 2. **Weekly CPK** (daptomycin myopathy) 3. **Blood cultures** (clearance by 48-72 hours expected) 4. **Echocardiography** (vegetation size; complications) 5. **Therapeutic drug monitoring** when available

Why PICC Placement Is Absolutely Contraindicated

Reasoning: 1. Excellent alternative (dialysis access) available 2. Small-bore IJ catheter option if additional access needed 3. PICC causes permanent vascular damage (documented 7-57% thrombosis rates) 4. Damages vessels critical for future dialysis access 5. Professional guidelines unanimously prohibit PICC in CKD stage 4-5

Medico-Legal Implications: - Explicit guideline recommendations against PICC use - Clear documentation of superior alternatives - Predictable vascular complications - Healthcare system liability substantial if PICC complications occur - Recommendation: Hard stops in electronic ordering systems requiring nephrology approval for any patient with eGFR <60 mL/min/1.73m²

Section 7: Access Functionality Assessment and Monitoring

Pre-Dialysis Assessment Checklist

Component	Assessment	Normal Finding	Concerning Finding
Bruit	Auscultation over access	Continuous whooshing	Absent ☐ clotting/stenosis

Component	Assessment	Normal Finding	Concerning Finding
Thrill	Palpation along access	Continuous vibration full length	Absent ☐ concern for stenosis
Appearance	Visual inspection	No unusual swelling/discoloration	Edema, erythema ☐ infection
Temperature	Palpation	Warm; slightly elevated vs. contralateral arm	Cool ☐ possible steal syndrome
Cannulation ease	Needle insertion	Brisk blood flow into tubing	Sluggish flow ☐ access dysfunction
Hemostasis	Post-dialysis	Bleeding stops with pressure in <10 min	Prolonged bleeding ☐ concern for anticoagulation/access trauma

Access Flow Monitoring

Methods: 1. **Qualitative (bedside):** Observe cannulation difficulty, flow rate during treatment 2. **Quantitative (ultrasound dilution or thermal dilution):** Direct measurement of mL/min

Monitoring Frequency: - Monthly minimum (assess adequacy) - More frequent if clinical concern (loss of bruit/thrill, difficult cannulation)

Intervention Thresholds: - Flow <500 mL/min: Investigate for stenosis - Flow <300 mL/min: Likely inadequate for standard dialysis - Progressive decline: Trend analysis important (acute drop vs. gradual decline)

Practice Questions

1. A patient on hemodialysis has a functioning AVF. You note loss of the previously palpable thrill over the access. What is the most likely diagnosis?

- A) Aneurysm formation
- B) Steal syndrome
- C) Venous stenosis
- D) Infection

Correct Answer: C) Venous stenosis *Loss of thrill indicates loss of turbulent flow, typically from stenosis at the venous anastomosis or downstream. Aneurysm would have palpable pulsatility. Steal syndrome would have an audible bruit. Infection might be present but thrill loss indicates hemodynamic problem.*

---

2. A dialysis patient with CKD stage 5 being treated for bacteremia is scheduled for PICC line placement for antibiotics. What is the appropriate response?

- A) Approve PICC placement as planned
- B) Consult nephrology to discuss alternatives before proceeding
- C) Obtain informed consent specifically for risk of central venous stenosis
- D) Place the PICC but limit dwell time to <3 weeks

Correct Answer: B) Consult nephrology to discuss alternatives before proceeding *PICC lines are contraindicated in ESRD patients due to high thrombosis rates (23-57%) and damage to vessels critical for dialysis access. This patient should be offered alternatives: (1) administration via dialysis access if infection timing allows, or (2) small-bore tunneled IJ catheter if immediate daily dosing essential.*

---

3. A 70-kg hemodialysis patient with enterococcal endocarditis (native valve) is stable. You propose extended-interval daptomycin dosing post-dialysis rather than ampicillin-ceftriaxone daily therapy. Which pharmacokinetic principle justifies this approach?

- A) Daptomycin is not removed by dialysis
- B) Daptomycin's half-life is 3-6x longer in ESRD than normal renal function
- C) Daptomycin doesn't require therapeutic drug monitoring
- D) All dialysis patients tolerate daptomycin better than ampicillin

Correct Answer: B) Daptomycin's half-life is 3-6x longer in ESRD than normal renal function *Daptomycin is highly protein-bound and has minimal renal clearance. In ESRD, its half-life extends from 8-9 hours to 28-52 hours, allowing 48-72 hour dosing while maintaining therapeutic levels. This justifies post-dialysis administration every 48 hours.*

Key Takeaways

1. **Access assessment:** Bruit and thrill are critical clinical findings; loss suggests stenosis or thrombosis

2. **Access hierarchy:** Fistula » Graft » Catheter in terms of infections, longevity, and flow
3. **PICC prohibition:** Absolutely contraindicated in dialysis patients; 23-57% thrombosis rates cause permanent vascular damage
4. **Superior alternatives:** Use dialysis access when possible; if additional access needed, small-bore IJ catheter
5. **Pharmacokinetic principles:** Extended drug half-lives in ESRD enable extended-interval dosing for highly protein-bound drugs
6. **Extended-interval endocarditis therapy:** Daptomycin + ceftriaxone post-dialysis practical alternative to daily ampicillin-ceftriaxone

---

Related Resources

- Enterococcal IE Management
- CCHT Exam Module (Access assessment section)
- Dialysis Student Guide
- Nephrology Hub

Created for PA and medical students as part of nephrology education. For clinical management decisions, consult current guidelines, institutional protocols, and attending nephrologists. All PICC placements in CKD stage 4-5 should require explicit nephrology approval and documentation of superior alternatives considered.