Peritoneal Dialysis: Physiology, Adequacy & Complications

Andrew Bland, MD, FACP, FAAP

July 2026

Peritoneal Dialysis: Physiology, Adequacy & Complications

Peritoneal Membrane Anatomy & Function

The peritoneal membrane: - Large surface area (~2 m^2; roughly size of adult skin) - Highly vascularized (rich blood supply) - Semipermeable — allows water, electrolytes, small uremic toxins to cross - **Acts as dialyzer** when dialysate is instilled into peritoneal cavity

Key Anatomical Points

- **Visceral peritoneum:** Covers organs (bowel, liver, spleen)
- **Parietal peritoneum:** Covers abdominal wall and diaphragm
- **Peritoneal cavity:** Normally <50 mL serous fluid; expands to accommodate ~2 L dialysate

---

Transport Mechanisms: How PD Works

1. Diffusion

Concentration gradient: Solutes move from high (blood) to low (dialysate) concentration

Molecular weight dependency: - **Small solutes:** Urea, creatinine, K (cross easily in early dwell; rapid diffusion) - **Medium solutes:** β2-microglobulin, phosphate (slower clearance) - **Large solutes:** Albumin, proteins (cross poorly; protective for nutrition)

Rate determined by: - Capillary pore density - Diffusion distance - Dwell time (longer dwell = more diffusion)

2. Ultrafiltration (Convection)

Osmotic gradient: Dextrose or icodextrin in dialysate draws water from blood

Mechanism: - Dextrose (glucose) in dialysate → osmotic gradient → water follows (osmosis) - Water carries small solutes with it (solvent drag)

Dextrose concentrations: 1.5%, 2.5%, 4.25% - **1.5% dextrose:** Mild UF; ~400–600 mL fluid removal per exchange - **2.5% dextrose:** Moderate UF; ~600–900 mL per exchange - **4.25% dextrose:** Aggressive UF; ~1–2 L per exchange (rarely used; hyperglycemia risk)

[!tip] **Clinical pearl:** Dextrose absorbed systemically → hyperglycemia risk. ~50–80% of dextrose absorbed over 4-hour dwell. Diabetics may need insulin adjustment.

3. Lymphatic Absorption

- Peritoneal lymphatics also absorb some fluid + solutes
- **Reabsorption of UF:** Even with hypertonic solution, some UF reabsorbed by lymphatics
- Mechanism not fully understood; limits maximum UF achievable

---

PET Test: Peritoneal Equilibration Test

What it measures: How quickly solutes equilibrate across peritoneal membrane

How it's done: 1. Install 2 L of standard PD solution (1.5% dextrose) 2. Dwell for 4 hours 3. Draw samples of dialysate at 2h and 4h (also baseline serum creatinine) 4. Calculate: **D/P ratio** = dialysate Cr / plasma Cr

PET Classification

Category	D/P Ratio @ 4h	Membrane Characteristics	Clinical Implications
High	>0.81	Fast equilibration; rapid solute transfer	Fast peritoneal clearance; rapid UF loss (solute reabs.)
High-Average	0.61–0.81	Moderately fast	Good balance of solute + UF
Low-Average	0.41–0.60	Slow equilibration	Requires longer dwells; good UF retention
Low	<0.41	Very slow; small pores	Excellent UF; slow solute removal

Clinical Decisions Based on PET

High transporters: - Short dwells (2–3 hours) - May struggle to maintain UF (solutes reabsorbed quickly) - Nocturnal APD (longer total dwell time; smaller dwells to maximize clearance)

Low transporters: - Longer dwells (4–6 hours) to maximize diffusion - Excellent UF retention (can use lower dextrose) - May be suitable for CAPD

High-average or low-average: Most flexible; suitable for CAPD or APD

[!warning] **Peritoneal transport can change over time** — repeat PET every 1–2 years if significant change in adequacy.

CAPD vs APD: Modality Comparison

CAPD (Continuous Ambulatory Peritoneal Dialysis)

Prescription: - 4–5 exchanges per day - ~2 L per exchange - Dwell times: 4–6 hours during day, overnight dwell 8–12 hours

Workflow: 1. Drain previous exchange 2. Install fresh dialysate (manual infusion; gravity-assisted) 3. Disconnect; carry with catheter capped during dwell 4. Repeat 4–5×/day

Advantages: - Patient control; flexible timing - No machine required - Gentle ultrafiltration (less glucose load) - Preserves residual renal function well

Disadvantages: - High technique failure (patient must perform correctly; contamination risk) - Peritonitis risk higher (more exchange connections) - Body image (visible abdominal catheter; bulge from fluid) - Workload (5×/day exchanges = 45+ min/day minimum) - Clearance lower than APD if low transporter

---

APD (Automated Peritoneal Dialysis)

Prescription: - Machine cycles 8–10 exchanges overnight (8–10 hours) - Daytime optional exchange (1–2 L, 4–6 hour dwell) - Cycles usually every 2–3 hours at night

Workflow: 1. Connect cycler tubing to catheter before bed 2. Cycler automatically fills, dwells, drains 3. Disconnect in morning; resume daily activities 4. Optional daytime exchange

Advantages: - **Less frequent exchanges** (more flexibility) - **Higher total clearance** (longer total PD hours) - Better solute removal for high transporters - **Reduced peritonitis risk** (fewer connections; cycler is automated) - Daytime peritoneal-free time (comfort, social, work flexibility) - Better suited for working patients

Disadvantages: - **Machine cost:** ~$3,000–5,000 (expensive; insurance coverage variable) - Nightly connection required (less flexibility for travel) - Potential sleep disruption (machine noise, tube movement) - Increased dialysate use (cost ~$8,000–12,000/year vs $5,000–8,000 for CAPD)

PD Solutions & Composition

Standard Solutions (Dextrose-Based)

Component	Concentration	Function
Dextrose	1.5%, 2.5%, 4.25%	Osmotic agent (UF)
Sodium	132 mEq/L	Electrolyte balance
Potassium	0 mEq/L	Allows K removal
Calcium	3.5 mEq/L	Maintains Ca balance
Magnesium	0.5 mEq/L	Electrolyte
Chloride	96–101 mEq/L	Electrolyte; prevents acidosis
Bicarbonate/Lactate	35–40 mEq/L	Acid-base balance

Component	Concentration	Function
Glucose	As osmotic agent	—

Alternative Solutions

Icodextrin (glucose polymer): - Osmotic agent; slow absorption - Better for long nocturnal dwells (preserves UF throughout dwell) - Less hyperglycemia than dextrose - **Cost:** Higher; insurance may require prior authorization

Amino acid-based PD: - Contains amino acids instead of dextrose - Improves protein nutrition (protein loss in dialysate major issue) - Limited evidence; not routine

---

PD Adequacy: How to Know If Patient Is "Getting Enough"

Kt/V Calculation

Kt/V = dialysis adequacy metric: - K = peritoneal clearance (mL/min) - t = dialysis time (minutes) - V = body water volume (L)

Target: Kt/V $\geq$1.7/week (KDIGO recommendation)

How to assess: 1. **Peritoneal clearance:** Measured from 24-hour spent dialysate collection + urine 2. **Residual renal clearance:** Measured from 24-hour urine 3. **Total Kt/V = peritoneal Kt/V + renal Kt/V**

Urea Clearance (Ccr)

Target: $\geq$60 L/week/1.73 m² (peritoneal + renal combined)

Measured: 24-hour urine + dialysate collections; normalize to BSA

Clinical Assessment of Adequacy

Signs of inadequacy: - Persistent uremia (nausea, itching, fatigue) - Hypertension difficult to control - Anemia worsening (despite ESA) - Hyperkalemia (despite K-free solution) - Hyperphosphatemia (despite binders)

If inadequate: 1. Increase exchanges (add daytime exchange if APD) 2. Increase dwell volumes (from 2 L to 2.5 L, if tolerated) 3. Switch to APD if on CAPD 4. Consider transition to HD

Complications of PD

Peritonitis (~0.4 episodes/patient-year)

Risk factors: - Contamination during exchanges (major cause) - Catheter biofilm - Poor hand hygiene - Tunnel infections

Clinical presentation: - **Cloudy dialysate** (key finding; turbid/milky appearance) - Abdominal pain, tenderness - Fever (may be absent) - Nausea, vomiting

Diagnosis: - WBC >100/μL in dialysate (normally <50) - Positive culture (identify organism) - Gram stain

Treatment: 1. **Antibiotics** in dialysate (intraperitoneal) - **Empiric:** Vancomycin + ceftazidime (covers Staph, gram-negatives) - Duration: 10–14 days minimum - Continue during PD

2. **Monitor response:**
   - Dialysate should clear within 5–7 days
   - Repeat culture if not improving
3. **Failure to improve = catheter removal + transition to HD**

   [!tip] **Prevention:** Teach impeccable technique (hand hygiene, mask during exchanges, sterile connections). Antibiotic caps/discs on connectors reduce infection.

Catheter Complications

Complication	Mechanism	Management
Catheter migration	Tip moves out of pelvis	Reposition; if failed, replace
Catheter obstruction	Fibrin, omentum wrapping	Try flushing; ultrasound; possible surgery
Drainage problems	Obstruction during drain phase	Reassess position; reposition if needed
Tunnel/cuff infection	Bacterial colonization; abscess	Antibiotics; if failed, catheter removal
Leaks (early)	Defect at catheter insertion	Conservative: reduce volume, APD; surgical repair if large

Abdominal Wall Hernias

Incidence: ~40% at 5 years

Mechanism: Chronically elevated intra-abdominal pressure from dialysate + weakened fascia

Types: - Incisional hernia (at catheter insertion site) - Inguinal/umbilical hernia (more common with PD)

Management: - Small, asymptomatic: Observe; no intervention - Symptomatic or enlarging: Surgical repair (possible while continuing PD)

Encapsulating Peritoneal Sclerosis (EPS)

Definition: Fibrosis, inflammation, scarring of peritoneal membrane → eventual loss of function

Incidence: ~0.5–3% at 4 years; ↑ with longer PD duration

Risk factors: - Prolonged PD (>5 years) - Multiple peritonitis episodes - Eosinophilic peritonitis - Chlorhexidine exposure (old tubing)

Clinical presentation: - Gradual inadequacy (Kt/V ↓) - Abdominal pain, distension - Adhesions, bowel obstruction (rare but serious)

Management: - Transition to HD (if possible) - Consider immunosuppression (experimental; limited evidence) - Monitor closely; possible surgical intervention if bowel obstruction

---

Ultrafiltration Failure

Definition: Unable to achieve adequate fluid removal despite maximum osmotic strength (4.25% dextrose)

Causes: - High transporter (rapid solute reabsorption) - Aquaporin-1 dysfunction (water-only loss impaired) - EPS (rare) - Lymphatic reabsorption excessive - Sodium sieving (Na reabsorbs disproportionately; solute-free water follows)

Management: 1. **Switch to APD** (shorter dwells; preserve UF) 2. **Use icodextrin** (alternative osmotic agent) 3. **Transition to HD** if refractory

---

Protein Loss & Nutrition Management

Peritoneal protein loss: 1–2 g/day (more with higher dwell volumes, peritonitis)

vs Hemodialysis: 5–10 g/week (much less protein loss in HD)

Nutritional consequences: - Malnutrition risk - Visceral protein depletion (prealbumin ↓) - Muscle wasting

Management: 1. **Adequate dietary protein:** 1.2–1.3 g/kg/day (higher than HD) 2. **Adequate caloric intake:** 30–35 kcal/kg/day 3. **Monitor prealbumin, albumin** (yearly) 4. **Consider amino acid-based PD** (experimental; not routine) 5. **Avoid glucose overload** (reduce dextrose exposure; use icodextrin)

Related Resources

- Comprehensive PD Physiology & Management
- RRT Initiation & Modality Selection
- CRRT & Acute Dialysis

Self-Test Questions

1. **PET result: D/P ratio 0.85 (HIGH transporter)**
    - Recommendation: Short dwells (2–3h); consider APD for higher clearance
    - Why: Fast equilibration means prolonged dwells lose UF as solutes reabsorb
2. **PD patient with cloudy dialysate, 400 WBC/µL, gram-positive cocci**
    - Diagnosis: Peritonitis (likely Staph aureus)

- Treatment: Vancomycin + ceftazidime in dialysate × 14 days
- Monitor: Dialysate should clear; repeat culture at day 3–5

3. **Adequate CAPD with 4×2L exchanges daily; Kt/V 1.8; residual GFR 3 mL/min**
   - Assess: Adequacy is borderline good (goal >1.7)
   - Residual function: 3 mL/min helps; expect Kt/V to ↓ when RRF declines further
   - Action: Monitor closely; may need increase to 5 exchanges/day or APD if RRF lost

---

Version 1.0 | PA/Medical student level | Updated 2026-02-28

References: ISPD PD Adequacy & Transport Guidelines. KDIGO 2024 Dialysis Initiation, Adequacy & Complications. Peritoneal Dialysis Essentials: Physiology & Clinical Practice.