Hemodialysis (HD) & Peritoneal Dialysis (PD)

Thitinat D.

Take Home Messages

- HD
  - involves the perfusion of blood and dialysate on opposite sides of a semipermeable membrane.
  - Solutes are removed from the blood by diffusion and convection.
  - Excess plasma water is removed by ultrafiltration.
- PD
  - involves the instillation of dialysate into the peritoneal cavity via a permanent peritoneal catheter. The peritoneal membrane lines the highly vascularized abdominal viscera and acts as the semipermeable membrane.
  - Solutes are removed from the blood across the peritoneum via diffusion and ultrafiltration.
  - Excess plasma water is removed via ultrafiltration created by osmotic pressure generated by various dextrose or icodextrin concentrations.

Introduction

- The 3 primary treatment options for patients with ESRD are
  - Hemodialysis (HD)
  - Peritoneal dialysis (PD)
  - Kidney transplantation (KTx)
- HD was first successfully used in 1940, the procedure was not used widely until the Korean War in 1952.
- Permanent dialysis access was developed in 1960S.

HD

- **Advantages**
  - Higher solute clearance allows intermittent treatment
  - Parameters are better defined and can be detected early
  - Technique failure rate is low
  - Hemostasis parameters (due to intermittent heparinization) are better corrected
  - In-center HD enables closer monitoring of the patient
- **Disadvantages**
  - In-center hemodialysis requires multiple visits each week
  - Disequilibrium, dialysis-induced hypotension and muscle cramps are common
  - Infections may be related to the choice of membranes
  - Vascular access in frequently associated with infection and thrombosis
  - Decline of residual kidney function is more rapid compared to PD

PD

- **Advantages**
  - Hemodynamic stability due to slow ultrafiltration rate
  - Higher clearance of larger solutes
  - Better preservation of residual kidney function
  - Convenient IP route for drugs e.g. ATB and insulin
  - Suitable for elderly and very young patients
  - Freedom from the machine
  - Less blood loss and iron deficiency
  - No systemic heparinization required
  - SC vs IV EPO or DPO may reduce overall doses

PD

- **Disadvantages**
  - Protein and amino acid losses through peritoneum and reduced appetite
  - Risk of peritonitis
  - Catheter malfunction, and exit site and tunnel infection
  - Inadequate ultrafiltration and solute clearance in patients with a large body size
  - Risk of obesity with excessive glucose absorption
  - Mechanical problems such as hernias, dialysate leaks, hemorrhoids, or back pain
  - Extensive abdominal surgery may preclude PD
  - No convenient access for IV iron administration

HD: Principles

- HD consists of the perfusion of blood and a physiologic solution on opposite sides of a semipermeable membrane.
- Water, urea, creatinine, K, uremic toxins, and drugs, move from the blood into the dialysate, by either passive diffusion or convection as the result of ultrafiltration.

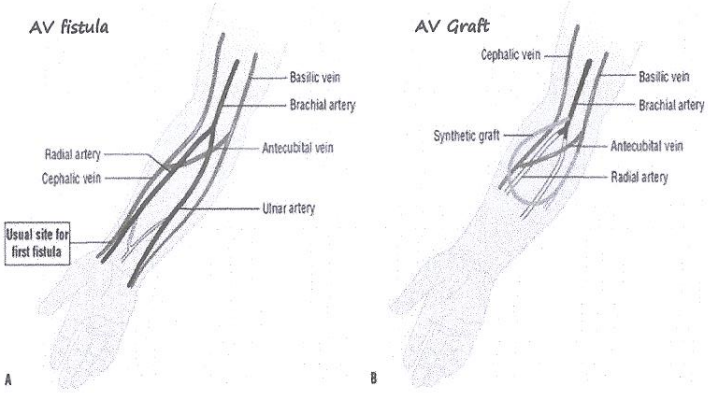
HD: Principles

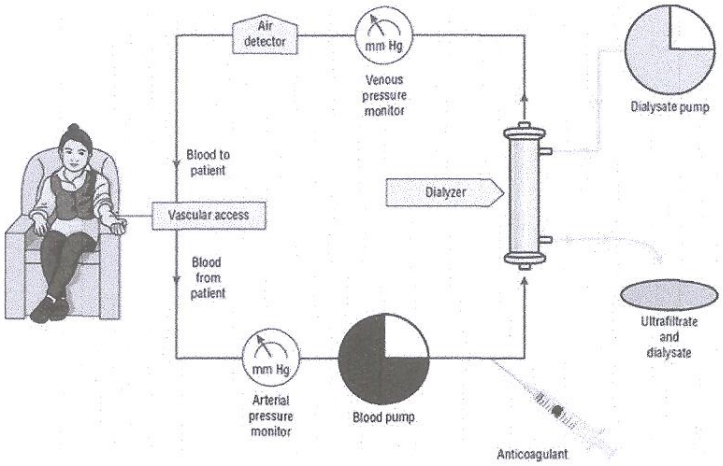
- **Diffusion:**
  - Is the movement of substances down a concentration gradient.
  - The rate of diffusion depends on the difference between the concentration of the solute in blood and dialysate, solute characteristics (size, water solubility, and charge), the dialyzer membrane composition and blood & dialysate flow rates.
  - Diffusive transport is rapid for small solutes
  - Other factors include the membrane thickness, porosity, and the steric hindrance between the membrane pore and solute

HD: Principles

- **Convection:**
  - Convection occurs when dissolved solutes are "dragged" across a membrane with water transport.
  - This occurs only if the pores in the dialyzer are large enough to allow them to pass along with water.
  - It can be maximized by increasing the hydrostatic pressure gradient across the dialysis membrane, or by changing to a dialyzer that is more permeable to water transport.
- **Ultrafiltration:**
  - It is the movement of water across the dialyzer membrane as a consequence of hydrostatic or osmotic pressure.
  - It is the primary means for removal of excess fluid.

HD ACCESS





HD Procedures

- 3 categories of dialysis membranes
  - Low flux
  - High efficiency
  - High flux
- Low-flux and high-efficiency membranes have small pores that limit clearance to relatively small molecules (size ≤ 500 Da) e.g. urea and creatinine.
- High-flux membranes are capable of removing high-molecular-weight endogenous substance e.g. β2-cicroglobulin and medications (vancomycin)
- HD is usually prescribed as 3 sessions weekly for 3 to 5 hours per session.

Common Complications

- **Hypotension**
  - Incidence 20-30%
  - Factors:
    - Hypovolemia and excessive ultrafiltration
    - Antihypertensive medications prior to dialysis
    - Target dry weight too low
    - Diastolic dysfunction, Autonomic dysfunction
    - Low calcium and sodium in dialysate
    - High dialysate temperature
    - Meal ingestion prior to or during dialysis

Common Complications

- **Hypotension: Management**
  - Place patient in Trendelenburg position
  - Decrease ultrafiltration rate
  - Give 100-200 mL bolus of NSS IV
  - Give 10-20 mL of hypertonic saline (20%) IV over 3-5 min
  - Give 12.5 g mannitol
  - Medications:
    - Midodrine 2.5-10 mg PO 30 min before HD
    - Droxidopa 100-600 mg PO 1 hr before HD
    - Levocarnitine 20 mg/kg IV after HD
    - Sertraline 50-100 mg daily
    - Fludrocortisone 0.1 mg before HD
    - DDAVP 1-2 IN sprays

Common Complications

- **Hypotension: Management**
  - Counsel patients:
    - Administer antihypertensive medications in the evening or after HD
    - Minimize intradialytic weight gain by decreasing salt content in their diet

Common Complications

- **Hypertension**
  - Incidence: 5-15%
  - Factors:
    - Plasma sodium concentration
    - Intravascular volume
    - Dialytic removal of antihypertensive medications
    - Activation of the RAAS
  - Management:
    - An increase in BP either during or post-HD may require a change in the delivery of a HD session and changes in antihypertensive medications or adjustments to the timing of medication administration.
    - Recent studies suggest switching metoprolol, atenolol and ACEIs to ARB, carvedilol or amlodipine.

Common Complications

- **Cramps**
  - Incidence 5-20%
  - Factors:
    - Muscle hypoperfusion due to ultrafiltration and hypovolemia
    - Hypotension
    - Electrolyte imbalance, acid-base imbalance
  - Management
    - Acute: give 100-200 mL bolus of IV NSS, 10-20 mL of IV hypertonic saline (20%) over 3-5 mins, 50 mL of 50% IV glucose
    - Medications: vitamin E 400 IU at bedtime, Quinine 300 mg daily

Common Complications

- **Nausea and vomiting**
  - Incidence 5-15%
  - Factors:
    - Hypotension
    - Dialyzer reaction
- **Headache**
  - Incidence 5%
  - Factors:
    - Disequilibrium syndrome
    - Caffeine withdrawal due to dialysis removal

Common Complications

- **Pruritus**
  - Incidence 5%
  - Factors:
    - Inadequate dialysis
    - Skin dryness
    - Secondary hyperparathyroidism
    - Abnormal skin concentrations of electrolytes
    - Histamine release
    - Mast cell proliferation

Common Complications

- **Chest and back pain**
  - Incidence 2-5%
  - Factors:
    - Unknown
- **Fever and chills**
  - Incidence < 1%
  - Factors:
    - Endotoxin release
    - Infection of dialysis catheter

Vascular Access Complications

- Thrombosis and infection are the most common.
- Oral antiplatelet agent's role for the prevention of vascular access thrombosis has been controversial since efficacy is not well established and there is an increased risk of bleeding.
- The use of warfarin to maintain vascular access patency remains controversial with some trials suggesting an increase in morbidity and mortality.
- Catheter-locking solutions with UFH, rt-PA or sodium citrate instilled in each HD catheter lumen between HD sessions have been associated with a reduction in catheter thrombosis. Sodium citrate 4% is as effective as UFH but may offer a better safety profile at a reduced cost.

Vascular Access Complications

- Alternatives for management of venous catheter thrombosis:
  - Alteplase
    - Instill 2 mg/2mL per catheter lumen port: attempt to aspirate after 30 min; may repeat dose if catheter function is not restored in 120 min.
    - Alteplase has also been given as a short infusion of 2 mg/h over 4 hours for a blocked catheter and 1 mg/hr over 4 hours for sluggish blood flow.
  - Reteplase
    - Instill 0.4 U/0.4 mL in each lumen, attempt to aspirate after 20-30 min, may repeat if necessary

Vascular Access Complications

- Infection is a leading cause of mortality in HD patients.
- The most prevalent pathogens for BSIs were Gram-positive (64%), Gram-negative (35%) and Candida species (0.2%).
- The most frequently isolated micro-organism were: *S.aureus* (31.8%), *S.epidermidis* (15.6%), coagulase-negative *staphylococcus* (9.7%), *E.faecalis* (4.9%) and *E.coli* (2.9%).
- The incidence with MRSA was 39.5% and cephalosporin-resistant *E.coli* was 17.8%.

Vascular Access Complications

- When an AV fistula infection is suspected, empiric broad-spectrum ATB must be initiated usually with vancomycin + aminoglycoside.
- If the infection is confirmed, should continue for a total of 6 weeks and should be tailored to culture sensitivities.
- A suspected infection in an AVG may require more than ATB therapy alone, and a surgical procedure to remove the infected graft material may be needed.
- Preventative care includes minimizing the use and duration of catheters, proper disinfection and sterile technique and the use of an antimicrobial ointment at the exit site (mupirocin 2%, providone-iodine).

PD: Principles

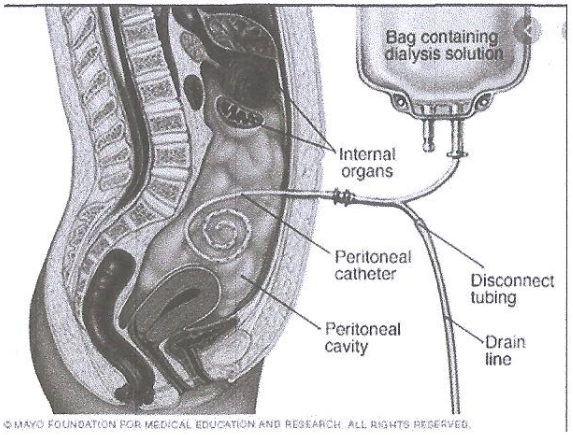
- In PD, the dialysate-filled compartment is the peritoneal cavity, into which dialysate is instilled via a peritoneal catheter that traverses the abdominal wall.
- The peritoneal membrane that lines the cavity functions as the semipermeable membrane, across which diffusion and ultrafiltration occur.
- The peritoneal dialyzing membrane is comprised of a monocellular layer of peritoneal mesothelial cells, basement membrane and underlying connective and interstitial tissue.
- Blood vessels supplying and draining the abdominal viscera, musculature and mesentery constitute the blood-filled compartment.

PD: Principles

- Unlike HD:
  - PD cannot be manipulated to maximize solute and fluid removal because the blood is not in intimate contact with the dialysis membrane, metabolic waste products must travel to the dialysate-filled compartment.
  - There is no easy method to regulate blood flow to the surface of the peritoneal membrane, nor is there a countercurrent flow of blood and dialysate to increase diffusion and ultrafiltration via changes in hydrostatic pressure.
- The available means to enhance PD clearance involve alterations in dialysate volume, dwell time, and the number of exchanges per day.

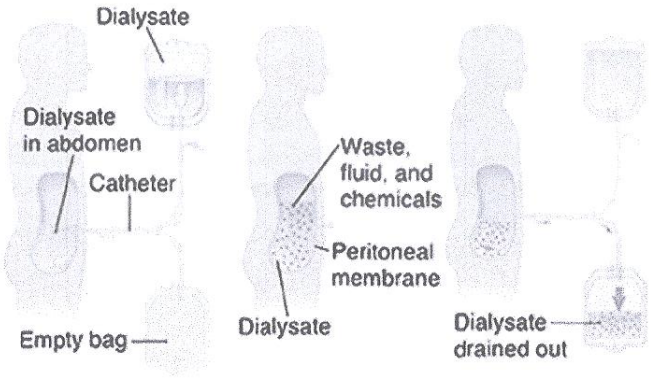
PD Access

- Access to the peritoneal cavity is via the placement of an indwelling catheter with 40-45 cm long and 20-22 cm inside the cavity.
- The remainder of the central section of the catheter is tunneled subcutaneously before exiting the abdominal surface.
- The external section of most peritoneal catheters ends with a Luer-Lok connector.



PD Procedures

- PD require the placement of a dialysis solution to dwell in the peritoneal cavity for some period, removing the spent dialysate, and then repeating the process.
- PD may be altered by changing the number of exchanges per day, by altering the volume of each exchange, or by altering the strength of dextrose or other osmotic agent in the dialysate for some or all exchanges.
- Typically a patient instills 2-3 L of dialysate 3 times during the day with each exchange lasting 4-6 hours, and then a single dialysate exchange overnight lasting 8-12 hours.



PD Procedures

- Continuous Ambulatory Peritoneal Dialysis (CAPD)
  - Manually
  - Automated systems: Automated Peritoneal Dialysis (APD)
- APD device is set up tin the evening, and the patient attaches the peritoneal catheter to it at bedtime. The machine performs several short-dwell exchanges (usually 1-2 hours) during the night. This permits a long cycle-free daytime dwell of up to 12-14 hours.
- The APD systems include: continuous cycling PD, tidal PD and nightly intermittent PD

PD Solutions

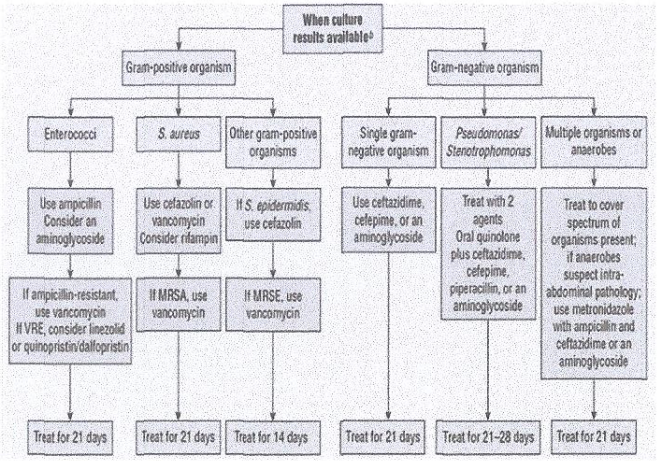
- They are commercially available in volumes of 1-3 L in PVC plastic bags.
- The most commonly used solutions contain glucose (dextrose 1.5%, 2.5%, 3.86%, 4.25%) or icodextrin(7.5%) with varying concentrations of electrolytes, such as Na (132 mEq/L), Cl (96 mEq/L), Ca (2.5-3.5 mEq/L), Mg (0.5 mEq/L) and lactate (40 mEq/L).
- Icodextrin produces prolonged ultrafiltration and may have fewer of the metabolic effects associated with dextrose, e.g. hyperglycemia and weight gain.

PD Complications

Complication	Cause	Treatment
Exacerbation of DM	Glucose load	IP insulin
Exacerbation of HF, Edema, Pulmonary congestion	Fluid overload	Increase ultrafiltration Diuretics (if has residual RF)
Hyper-/ Hypocalcemia	Electrolyte abnormalities	Alter dialysate Ca content
Chemical peritonitis	PD additives	Discontinue PD additives
Albumin Loss, Loss of AA, Muscle wasting, increased adipose tissue	Malnutrition	Dietary changes, Parenteral nutrition, Discontinue PD
Fibrin formation in dialysate	Unknown	IP insulin

Peritonitis

- Guidelines suggest that peritonitis is an elevated dialysate WBC count > 100/mL (0.1×10^9/L) with at least 50% polymorphonuclear neutrophils indicates the presence of inflammation.
- A patients presents with abdominal pain and a cloudy effluent.
- The majority of infections are caused by gram-positive bacteria, of which *S. epidermidis* is the predominant organism.
- Final choice of therapy should always be guided by culture and sensitivity results.



Peritonitis

- The preferred delivery route for ATB is IP over IV therapy for the treatment of peritonitis.
- The drug concentrations of sing IP antibiotic dose achieved in dialysate and serum differ between intermittent (one exchange per day) and continuous methods (all exchanges).
- Intermittent IP therapy necessitates that a sufficient amount of drug transfers from the peritoneal cavity to the systemic circulation, thus allowing drug to diffuse back into the peritoneum drug-free dialysate dwell time(s).
- Once daily dosing requires drug(s) be added to the exchange with longest dwell time (at least 6 hours) to ensure maximum systemic exposure.

Peritonitis

- Continuous dosing recommendations may require a loading dose with the very first IP dose and a maintenance dose for each subsequent exchange.
- The ISPD guidelines recommend continuous dosing of a first-generation cephalosporin because of concerns over inadequate IP drug concentration during the shorter APD dialysate dwells.
- Fungal peritonitis is associated with a poor prognosis and high morbidity and mortality. ISPD recommendations are to remove the catheter immediately after identifying fungi.

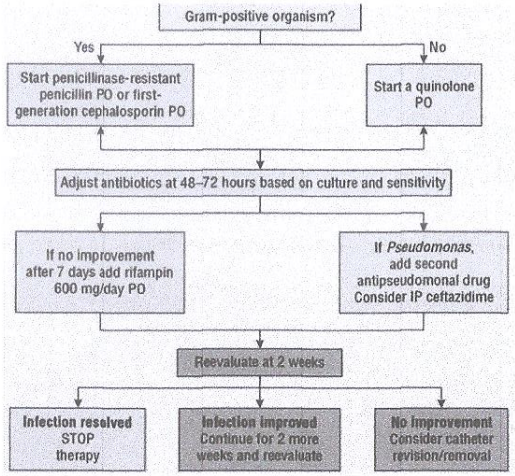
Drug	Intermittent (one exchange daily)	Continuous (all exchanges)
Aminoglycosides		
Amikacin	2 mg/kg	LD 25 mg/L; MD 12 mg/L
Gentamicin	0.6 mg/kg	LD 8 mg/L; MD 4 mg/L
Netilmicin	0.6 mg/kg	MD 10 mg/L
Tobramycin	0.6 mg/kg	LD 3 mg/kg; MD 0.3 mg/kg
Cephalosporins		
Cefazolin	15–20 mg/kg	LD 500 mg/L ; MD 125 mg/L
Cefepime	1,000 mg	LD 250–500 mg/L; MD 100–125 mg/L
Cefoperazone	ND	LD 500 mg/L ; MD 62.5–125 mg/L
Cefotaxime	500–1,000 mg	ND
Ceftazidime	1,000–1,500 mg	LD 500 mg/L; MD 125 mg/L
Ceftriaxone	1,000 mg	ND
Penicillins		
Amoxocillin	ND	MD 150 mg/L
Ampicillin	ND	MD 125 mg/L
Penicillin G	ND	LD 50,000 units/L; MD 25,000 units/L
Quinolones		
Ciprofloxacin	ND	MD 50 mg/L
Others		
Vancomycin	15–30 mg/kg QS-7d[1]	LD 30 mg/kg; MD 1.5 mg/kg/bag
Daptomycin	ND	LD 100 mg/L; MD 20 mg/L
Aztreonam	2 g	LD 1,000 mg/L; MD 250 mg/L
Teicoplanin	15 mg/kg q 5 days	LD 400 mg/bag; MD 20mg/bag
Linezolid	ND	Oral 200–300 mg daily

Systemic Antibiotic Dosing Recommendations

Drug	Dosing
Ciprofloxacin	Oral 250 mg twice daily
Levofloxacin	Oral 250 mg daily
Moxifloxacin	Oral 400 mg daily
Ertapenem	IV 500 mg daily
Linezolid	IV or oral 600 mg twice daily
Rifampicin	450 mg daily for body weight ≤50 kg, 600 mg daily for body weight ≥50 kg
Trimethoprim/ Sulfamethoxazole	Oral 160 mg/800 mg twice daily
Amphotericin	IV test dose 1 mg; starting dose 0.1 mg/kg/day over 6 hours increase to target dose 0.75–1.0 mg/kg/day
Caspofungin	IV 70 mg load, then 50 mg daily
Fluconazole	Oral 200 mg loading, then 50 mg daily
Flucytosine	Oral 1 g daily
Posaconazole	IV 400 mg every 12 hours
Voriconazole	Oral 200 mg every 12 hours

Catheter-Related Infections

- A CRI in patients includes both exit-site infection (ESI) and tunneled infection.
- The majority of ESI are caused by *S.aureus*.
- Although Pseudomonas are less common, they can result in significant morbidity.
- The characteristics include the presence of purulent drainage, with or without erythema at the catheter exit-site.
- Topical antibiotics and disinfectants appear to be effective agents for the prevention of ESIs.



Catheter-Related Infections

- Prevention peritonitis and CRI include refinement of connector system technology (Luer-Lok connectors), enhanced patient training techniques, and the use of prophylactic ATB regimens and vaccines.
- DM patients and those on immunosuppressive therapy are at increased risk for *S.aureus* CRI.