

Hemodialysis Study Guide

Anatomy of kidney

Nephron: Each kidney has 1 million nephrons. Only 25% of them are metabolically active at any given time. So the kidney has tremendous “resting potential”.

Blood supply: Some people have 2 renal arteries, which presents a problem for transplant. The glomerulus is made up of 50 capillaries 20 times more permeable than other capillaries in the body. Kidneys receive 1000ml of blood per minute. Total kidney capillary surface area is 12m².

Cortex & Medulla: Cortex is primarily glomeruli, medulla is primarily tubules.

Juxtaglomerular apparatus: Unique endocrine structure, located between the afferent and efferent arterioles of each nephron. It secretes renin, which autoregulates renal blood flow and GFR. GFR is 125ml/min. of which only 1ml is excreted as urine. Autoregulation is absent at MAP of < 70mmHg

Causes of Renal Failure

ARF = **Pre-renal:** CHF, tamponade, valve disease, MI, sepsis, anaphylaxis, trauma, hemorrhage, DI, peritonitis, pancreatitis, burns, DKA

intra-renal: glomerulonephritis, scleroderma, ATN, nephrotoxins

post renal: kidney stones, tumors, blood clots, BPH, urethral strictures
neurogenic bladder

CKD = Diabetes, HTN, glomerulonephritis, ATN, congenital causes like PKD, prune-belly, Allport syndrome.

Renal Physiology

Receive ¼ of cardiac output

Excretes wastes

Regulates fluid balance and osmolality

Metabolically changes vitamin D from inactive form to active form

Regulates electrolytes: calcium, phosphorus, sodium, potassium

Helps maintain acid-base balance

Secretes renin and prostaglandins

Produces erythropoietin

Insulin degradation

Systemic Manifestations

Integumentary –	Dryness, pruritis, ecchymoses, changes in pigmentation d/t urochromes, purpura
Cardiovascular -	Fluid overload, hypertension, dysrhythmias, pericarditis, S3 gallop
Respiratory -	Pulmonary edema, pneumonia, Kussmaul respirations
Hematologic -	Anemia, fatigue, alterations in coagulation, RBCs live only 60 days vs 120 in normal person
Gastrointestinal -	Anorexia, halitosis, nausea & vomiting, gastritis, bleeding, gastroparesis, poor nutritional status, vitamin deficiencies
Neurological -	Drowsiness, headache, confusion, apathy, irritability
Musculoskeletal -	Hypocalcemia, hyperphosphatemia, metastatic calcifications, muscle twitching, bone disease, restless leg syndrome
Eyes	Red eyes of uremia
Metabolic Changes -	electrolyte imbalances, metabolic acidosis
Immune System -	Impaired lymphocyte & granulocyte function. Less phagocytosis
Hypothalamus -	Impaired thermoregulation = cold intolerance, low body temp

Dietary and Fluid Restrictions

1000-1200ml total fluid/24 hrs

Low potassium, low sodium foods (2 gm Na 40-80mEq) (2-3gm/day K+ 50-75mEq)

High biological proteins (1.2gm/kg/day). Pre-ESRD restriction is 0.4 – 0.6gm

Take phosphorus binders

Principles of Hemodialysis:

- Osmosis, diffusion, convection, solute drag
- Membrane resistance to diffusion will be high if the dialyzer membrane is thick, or the pores are small. Thin membranes with large holes are called high-flux membranes. Water molecules are extremely small and can pass through all membranes.
- Kinetic Modeling: To measure dialysis adequacy, measure urea removal, and plasma levels of urea. The simplest formula is the URR (urea reduction ratio)
 $R = \text{post BUN} / \text{pre BUN} \quad 1.0 \text{ minus } R = \text{URR}$
- Kt/V is a measure of the amount of plasma cleared of urea over the time of dialysis, and based on the pts total body water. CMS has established a $Kt/V \geq 1.2$ to be adequate dialysis, and 1.4 to be adequate dialysis for diabetics. This equates to a URR of 65 - 70%
- The KoA of a dialyzer is the mass transfer coefficient. It is a measure of the efficiency of a dialyzer to remove urea. High KoA dialyzers need to be used for large patients, especially men.
- KUf is the ultrafiltration coefficient. It refers to the water permeability of the dialyzer: the number of mm of fluid per hours that will be transferred across the membrane per mmHg pressure gradient.

- Two types of recirculation occur during dialysis, and both reduce the effective urea clearance: cardiopulmonary recirc and access recirc. In cardiopulmonary circulation, the “cleaned” blood is sent back to the heart via the AVF/AVG without passing through the systemic vascular bed. (cardiopulmonary recirc does not occur with venous catheters). The degree of cardiopulmonary recirc is about 4%. Access recirc is blood entering the dialyzer has been “diluted” with blood that has just left the dialyzer...about 4-7%.

- TMP greater than 500 can rupture the dialyzer membranes.
- In general the BFR should be 4 times the body weight in kg.
- Dialysate flow rate. Increasing the rate from 500 to 800 delivers 10% better clearance of waste products.
- The purpose of having the blood and dialysate run countercurrent is to maximize the concentration difference of waste products between blood and dialysate in all parts of the dialyzer.
- Backfiltration is a potential problem with high-flux membranes. If the pressure difference between the blood and dialysate compartments gets too low, pyrogenic material from the dialysate can be pulled into the pts blood compartment.
- Dialysis solution heated to $> 42^\circ$ can cause hemolysis.

- The blood leak detector is placed in the dialysate outflow line. If it detects a leak in the membrane, an alarm will sound. Test with a hemostix. If it is a small leak, it is acceptable to return the patient’s blood. If it is a large leak do not return the blood. Discard the whole circuit.
- The Braun dialysis machines are volumetric ultrafiltration systems.
- Asahi dialyzers are sterilized with gamma-irradiation.
- Prepare needle sites with a full 3 minute scrub with betadine or alcohol.

Vascular Access

Catheters

Subclavian causes stenosis, Jugular most common,
Femoral prone to infection, IVC last resort.

Right Jug is preferred over left, because the lung and pleura are lower on R than L.
Right jug is also a relatively straight path to atrium.

AV fistula

Upper arm avf/avg can contribute to CHF since they shunt blood back to the heart. Non-dominant arm preferred.

AVF can be side-to side, or side to end. It takes 2 months to mature. Use the entire length of fistula for cannulation, or button-hole technique.

“Steal syndrome” is when the circulation in the hand is compromised by the AVF.

AVGraft

Can be used in 2-3 weeks. Vectra grafts can be used right away.

Average graft patency rate 18 mos.

The most common reason for poor flow is stenosis at the venous anastomosis site.

Balloon angioplasty can open stenoses. Frequent clotting, difficult needle placement, and a swollen arm all suggest stenosis. Venous pressure > 100mmHg at 200ml/min BFR suggests stenosis.

Life-site ports

Require special needles and procedure for initiating/discontinuing tx.

Anticoagulation Therapy

Heparin Sodium

“Tight” heparin therapeutic range is 1½ times base ACT. 30 minute half-life.

Stop 1hr early with fistulas/grafts. Factors favoring clotting: low BFR, high hct, high UF rate, transfusion.

Sodium Citrate

Lowers the calcium required for coagulation by infusing sodium citrate in the arterial line, then reversing it by infusing calcium chloride in the venous line. Rarely used because it requires frequent monitoring of calcium levels during dialysis. Very risky.

Low molecular weight heparin

Longer half-life usually only needs a bolus. But is very expensive

Heparin free

You may add heparin to the extracorporeal circuit, but be sure to spill this prime, or flush it with NS. Run a high BFR as possible. Periodically clamp the arterial line and rinse the system with NS flushes.

Dialysis Complications and Emergency Situations

Hypotension

- Any 30mmHg drop in systolic B/P should be treated.
- Common causes: high UF, dry wt too low, dialysate Na too low, warm dialysate, food ingestion, tissue ischemia, autonomic neuropathy (diabetics), antihypertensive meds, ischemic heart disease, valve disease, myocardial calcification, tamponade, septicemia, aging.
- More than 80% of the total blood volume is in veins, and therefore any change in venous capacity can cause decreased cardiac filling, decreased CO, and hypotension.
- Dialysis pts are slightly hypothermic. Their body temperature increases slightly during dialysis. Core heating is a powerful vasodilatory stimulus, resulting in venous and arterial dilatation. Use of a cooler dialysate can reduce this incidence.
- Eating food causes an increase in splanchnic venous capacity. The “food effect” on blood pressure lasts at least 2 hours. Avoid food before or during dialysis for patients who are prone to hypotension.
- During any hypotensive stress, the body releases adenosine. Adenosine blocks the release of norepinephrine, and has intrinsic vasodilator properties. In this sense, hypotension can amplify itself. Try to avoid hypotensive episodes.
- Pts with low hcts are more susceptible to hypotension.
- Treat with Trendelenberg, NS pour, no UF, O2. As an alternative to NS, HTS, glucose, mannitol, albumin can be used. Unless cramps are present, HTS has no benefit over regular NS.
- In acute renal failure, it is extremely important to avoid hypotension during dialysis. Transient episodes of hypotension can cause further renal damage and delay renal recovery.

Hypertension

- Major contributor to morbidity/mortality: atherosclerosis, LVH, stroke, dissecting aneurysm.
- Post dialysis B/P is the best indication whether antihypertensive drugs are required.
- In over 50% of pts, normotension will not be achieved by fluid removal. Attempts to UF can cause cramping, malaise, adverse cardiac or cerebral consequences, mesenteric ischemia or infarct.
- In a substantial % of pts, UF causes a paradoxical HTN. This signifies a state of relative dehydration. Do not continue to UF.

Air embolism

- Symptoms depend on the pts position.
- In seated patients, infused air will migrate to cerebral venous system without entering the heart, causing obstruction, loss of consciousness, convulsions, death.
- In recumbent pts, the air tends to enter the heart, pass from R ventricle to lungs, causing dyspnea, cough, chest pain, pulmonary air embolus.
- If air makes it across the capillary bed into Left ventricle, the result is air embolus in the brain or heart. Foam will often be seen in the venous blood line.
- Clamp the venous line. Stop the pump. Put pt on left side, Trendelenberg. Stat CXR, 100 % O₂, poss intubation.

Exsanguination

- Stop loss, volume expanders, stat labs and transfusion

Hemolysis

- Back pain, tightness in chest, SOB, blood appears like “cherry kool-aid” or port wine.
- Almost always a dialysate problem: hot dialysate, hypotonic solution, chloramines in the water.
- Clamp the lines, and do not return the blood. Hemolyzed blood has high K⁺ content.
- Delayed hemolysis of injured RBCs can continue for some time after dialysis.
- Must send off samples of dialysate for analysis.

First use syndrome

- Slow BFR, give Benadryl. Ethylene oxide used as a sterilant or cellulose membranes are common causes.

Cramps

- NS pour, Quinine in advance, HTS

Seizures

- Airway, NS, O₂, diazepam 5-10mg IV slowly - may repeat up to 30mg., stat BS, Ca, lytes. Phenytoin 10-15mg/kg slow IV – watch for bradycardia, AV block

Disequilibrium syndrome

- Occurs with rapid correction of advanced uremia. Restlessness, H/A, N&V, confusion, seizures. Brain swelling d/t a lag in osmolar shifts between blood and brain during dialysis.
- First dialysis should be short and gentle to reduce urea levels slowly over several days.

Nausea/vomiting

- Stop UF.

Dysrhythmias

- O₂, 12 lead EKG, NTG, drugs: lidocaine, atropine, verapamil

Pericarditis

- Auscultate for friction rub, paradoxical pulse > 10 mm Hg is the cardinal sign, chest pain worse when pt is supine; improves by sitting.
- Run heparin free, O₂. Usually dialyze 5-7 x/wk until it resolves.
- Pericarditis increases the risk of bleeding, arrhythmias, hypotension and tamponade.

Chest pain

- O₂, sublingual NTG, beta blockers, calcium channel blockers, no UF.

Metabolic Acidosis

- The amount of bicarb transfer to the pt is greatly reduced at high UF rates. So a higher than usual dialysis bicarb level might be needed in patients with a large weight gain.
- Pts with severe acidosis will have hemodynamic instability.

Infection Control

Hepatitis B	Isolate from other patients. Dedicated machine. Only 1% of pts have Hep B.
Hepatitis C	Fragile virus. Does not need isolation. Very common: 7-30% of pts.
HIV	Does not need isolated. Eligible for HIV+ transplant. 3% of pts.
Herpes zoster	Needs contact isolation
VRE	Needs contact isolation
MRSA	Needs contact or respiratory isolation, depending on source of infection.

In 50% of pts pre-dialysis temp is sub-normal. The access site is the source of 50-80% of bacteremia in dialysis pts. It can lead to endocarditis, meningitis, osteomyelitis, or septic emboli. Note redness, tenderness, exudates, low grade fever.

In dialysis pts, the incidence of UTI is high, esp pts with PKD.

Pneumonias are also high in dialysis pts.

Transfusions

RBC

Leukocyte-poor packed cells

Always ask if the physician wants leukopoor. Pt on transplant list or work-up will be delayed 400+ days if given reg RBCs d/t HLAs

Fresh frozen plasma

Salt-poor albumin

Expensive. Does not increase albumin stores for long term.

Assessing Hydrational Status

Breathing pattern During dialysis a modest fall in the arterial PO₂ can occur. In a pt with underlying pulm disease, they may need O₂. Dyspnea in the first ½ hour may be 1st use reaction or severe pyrogenic reaction. Severe hyperkalemia >7.0 mEq/L can cause resp failure d/t muscle weakness. Do not try to wean from ventilator during dialysis.

Cyanosis
Gallop heart rhythm
Neck vein distention
Ascites
Peripheral/periorbital/sacral edema
Weight

Assisting with Central Line Insertions

Collect all supplies. Position/shave patient. Observe monitor for ectopy when guide wire is inserted. CXR read. Charge for catheter.

Disequilibrium Syndrome

Check pupils
Bilat hand grasp
Speech
Response to noxious stimuli
Ability to move all extremities
Seizure precautions
Slow BFR
Give saline or colloids

SCUF or pure UF

Used when pt is hypotensive, but fluid overload. Removing only fluid uses the pts own solute load to help create a pressure gradient to pull fluid from interstitial space.

Medications

Hectorol, Zemplar	Vitamin D analog. Given to prevent/treat secondary hyperparathyroidism in CRF. Suppresses PTH. If Ca x P is >75, do not give.
Ferlecit, Venofer	Iron supplement. Give a test dose before initiating full dose. Give slowly. Too-rapid administration may cause hypotension, flushing, light-headedness, chest pain, malaise. Do not give if serum iron level is >300. Could cause iron toxicity.
Epogen, Aranesp	Stimulate RBC production. Infection reduces the response to EPO. Also needs normal iron stores. CMS does not reimburse cost of EPO for hgb > 12, unless there is proof you are decreasing the dose. Effects of a change in EPO can usually be seen in 7 days. Half-life IV is 8 hrs. Half-life subq is 18 hrs. Do not shake vials.
NaCl 23.4%	Hypertonic solution given to relieve muscle cramps. Too rapid infusion may cause venous irritation, hemolysis, cardiovascular shock, CNS disorders.
Mannitol	Osmotic solution to draw interstitial fluid into vascular compartment for hypotension. Side effects are rare.
50% dextrose	For low BS emergencies
Carnitine	A naturally occurring substance required in energy metabolism. Dialyzes out. If pts are hypotensive not r/t UF, or anemic & not responding to EPO, then it may be a carnitine deficiency. Use only the IV form in ESRD pts. Normal levels are 35-60. CMS guidelines for reimbursement is 25 or lower.
Midodrine	Is an alpha agonist that works on the alpha adrenergic receptors of the arteries and veins, producing an increase in vascular tone, and increased B/P. It does not stimulate cardiac receptors. Given PO, it peaks in 1/2-2 hours, and lasts for 3-4 hours.
Cardizem	Calcium channel blocker, antiarrhythmic. Used for rapid ventricular rates in a fib or atrial flutter. IV dose is 20mg for the average pt. Infusion is 5-15mg/hr.
Clonidine	(catapres) lowers renin and aldosterone
Captopril	(capoten) inhibits the conversion of angiotensin, decreasing renin effect

Calcium Gluconate	To increase calcium levels in hypocalcemia. Only 1/3 as potent as Calcium Chloride. Infusion 1gram, 200mg/min
Calcium Chloride	Use cautiously. 100 - 500mg infusion. Monitor VS closely. Will increase dig toxicity, and cause a moderate drop in B/P.
Protamine	Heparin antagonist. Ratio is 1mg protamine for 100units heparin. Never exceed 50mg in 10 minutes.
Vitamin K	Give SC or IM when possible; IV administration has caused death. Essential vitamin for production of 4 blood coagulation factors. Onset of action is 1-2 hours. Usually controls hemorrhage in 3-6 hours.
Gentamycin & Vancomycin	Hi flux dialyzers (like ours) remove both of these antibiotics, so check peak and troughs. Give last 30-60 minutes of dialysis.
Renalgel	dietary phosphorus binder
PhosLo	dietary phosphorus binder
Tums	dietary phosphorus binder (calcium)
Digoxin	These pts are at highest risk of arrhythmias during dialysis. Electrolyte shifts should be minimum – keep K+ 3.5, reducing bicarb to 20-30mEq/L will minimize intracellular shifting of K+
Morphine	The clearance of metabolites is decreased in CKD, resulting in a prolonged sedative effect.
Darvon, Wygesic	(Propoxyphene) is metabolized in the liver to a cardiotoxin, with a prolonged half-life in dialysis patients. Use with extreme caution in dialysis patients.
Demerol	Metabolizes to normeperidine, a convulsant, which they cannot excrete.. Do not use.
Aspirin	Should not be used d/t effect on bleeding time.
Vitamins	Need to replace water-soluble vitamins, folic acid, Vit B. Renal pts need special renal vitamin pills – not OTC – because they retain vit A & C

Lab Values

Hgb/hct	Hgb target 12.
Ferritin, % sat	Ferritin > 100, % Sat > 20. Need adequate iron stores for RBC production
Ca/Phos	Goal is Ca X P = / < 60. Greater than 60 = high risk for metastatic calcification. Pulse pressure > 50 is indication of calciphylaxis
K±	Hyperkalemia can be treated with calcium chloride or calcium gluconate to stimulate cardiac activity. D50 and reg insulin, or albuterol tx push the K+ back into the cell. The effect will last for 2-3 hours. Kayexalate is an exchange resin which changes Na+ for K+. Rectally it starts to work in 30 minutes. There is a 10-20% rebound of K+ 1-2 hours after dialysis
Albumin	Low albumin is a strong predictor of mortality.
BUN, creat	BUN not reliable. It is waste product of protein metabolism, so many conditions can cause elevation. Creatinine is a waste product of muscle metabolism. It is directly related to a change in kidney function.
Creatinine clearance	The amount of blood cleared of creatinine in one minute. Normal is 80-120. In diabetics, CMS requires < 15. In non-diabetics < 10 in order to be eligible for chronic dialysis.

Water Treatment Systems

Blending valve	Blends hot and cold water to proper temp for RO membrane
Water softener	Removes Ca and Mag
Carbon tanks	Remove chloride
Booster pump	Maintains pressure in the system
RO membrane	Removes
. Rejects > 90% of the water it processes	
Deionizing tanks	Remove any ions that carry a charge.
Sub-micron filter	Removes endotoxins
Backflow Preventer	Prevents treatment water from flowing back into water lines

Pts are exposed to about 120 liters of water during a dialysis tx.

AAMI (Association for the Advancement of Medical Instrumentation) has developed standards for water purity.

Hemolysis = copper, chloramine, nitrates.

Neurologic disease = aluminum

Hypertension = calcium & sodium

Anemia = copper, zinc

Hypotension = bacteria, endotoxins, nitrates

Bone disease = aluminum & fluoride

Bacterial count must be below 200 cfu (colony forming units).

Endotoxins < 2 EU (endotoxin units).

Hemoperfusion

- Uses a charcoal filter (which must be sterilized prior to use) for certain overdoses or poisonings.
- Best therapy for drugs that are protein bound or lipid soluble. tylenol, methaqualone, theophylline, glutethimide, digoxin, dilantin, tricyclic antidepressants, phenothiazine, chloral hydrate, diazepam.
- As a rule more heparin is required than with dialysis, because the charcoal absorbs some of the heparin.
- A single 3 hour treatment will substantially lower blood levels of most poisons. In more prolonged use the carbon cartridge becomes saturated.
- Thrombocytopenia can occur as a result of adsorption of platelets onto the cartridge. Watch for bleeding.
- May need 2nd hemoperfusion for rebound.

Peritoneal Dialysis

- Uses dextrose to control the amount of UF during an exchange.
- 9gms of protein loss/day across the peritoneal membrane.
- Is 1/8 as efficient as hemodialysis in altering blood solute, and 1/4 as efficient in terms of fluid removal. However, pt can do exchanges 4-6 x/day, vs 4 hours every other day of hemo. So in effect, there is not much difference in solute or fluid clearance.
- Principal contraindication is an unsuitable peritoneum d/t adhesions, fibrosis, malignancy.
- Principal reason for abandonment of PD is peritonitis.

CVVH

- Offers a gradual change in plasma solute composition and gradual removal of excess fluid, so it's better for patients who are hemodynamically unstable.

Transplant

- HLA – human leukocyte antigens – found on the surfaces of lymphocytes are used to determine tissue type. Each person inherits 2 from each parent. There are 60 known HLAs, thousands of combinations. Waiting time for transplant is 1-3 years. Diabetics who receive transplanted kidney start having diabetic changes in the kidney in 6 months.