

🧠 Topic: Kidney Replacement Therapy (KRT)

This includes:

- **Kidney transplantation** ✅ (best option) elective not emergent
- **Hemodialysis (most used)**
- **Peritoneal dialysis**

💠 Kidney Transplantation... The best!!!

➡ Kidney transplant is the **best treatment for most patients with ESRD (end-stage renal disease)** Because:

- It gives **longer survival**
- **Better quality of life**
- **Cheaper in the long term** compared to dialysis

💠 Hemodialysis (HD)

➡ This is the **most used method of dialysis**.

📅 When to start dialysis (indications):

These are **urgent or non-urgent reasons** to start dialysis:

Indication	What it means
1. CKD 5 (eGFR < 15 ml/min , for more than 3 months) with mild to moderate uremic symptoms, which are : n and v, itching, metallic taste	Not urgent — time to plan dialysis
2. Severe hyperkalemia not responding to meds	🚑 Emergency — can cause cardiac arrest
3. Severe metabolic acidosis (less than 7.1) not responding to meds- we tried giving bicarbonate	🚑 Emergency — life-threatening because it causes cellular shutdown and death
4. Severe fluid overload not responding to meds- tried giving IV loop diuretics	🚑 Emergency — causes pulmonary edema
5. Uremic encephalopathy	🚑 Emergency — confusion, coma from toxin buildup
6. Uremic pericarditis	🚑 Emergency — inflammation around the heart
7. Drug overdose (certain toxins)	🚑 Emergency — like lithium, ethylene glycol
8. Uremic bleeding	

📌 Summary:

- **#1** is not urgent — you have time to plan dialysis.
- **#2–#7** are urgent situations = **start dialysis immediately**

💠 When symptoms start, what's the first step?

"The first step is medical therapy"

✅ Before dialysis, we try medications (e.g. diuretics, bicarb) **if symptoms are mild**. But if there's **severe uremia, K⁺, or fluid**, you must **start dialysis**.

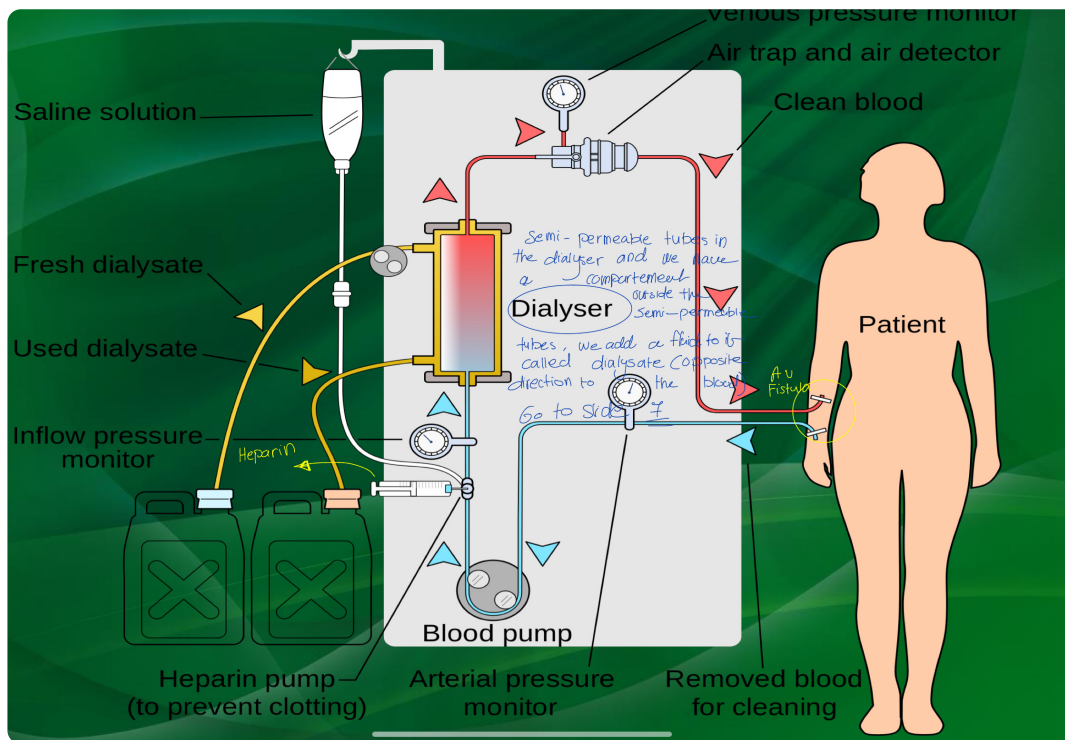
🔴 Hemodialysis:

"Hemodialysis is an extracorporeal therapy..." We try to **partially** replace a number of the key functions of kidney when the kidney is no longer sufficient

✅ This means blood goes **outside the body**, is cleaned, then returned. HD does the job of kidneys:

- Removes toxins (like urea)
- Removes excess water (remember most of patients do not urinate)
- Corrects high potassium
- Corrects acidosis

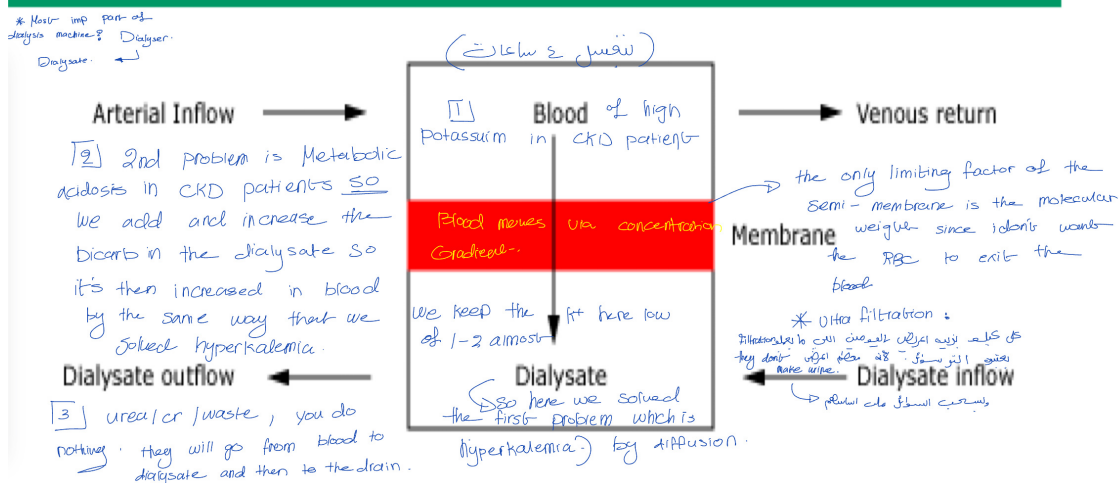
THESE ARE THE MAIN PROBLEMS THAT WE NEED TO FIX



Dialyzer (Artificial Kidney):

- Blood flows through **semi-permeable tubes**
- Dialysis fluid (dialyzer) is on the outside
- Wastes and K^+ **diffuse out of blood** into fluid
- Clean blood goes back to the body
- Think of it as a **filter** that works by:
 - **Diffusion** (for toxins, K^+)
 - **Ultrafiltration** (for water)

Schematic depiction of solute movement in dialysis



Concentrations of dialysate components used in hemodialysis

Sodium (mEq/L)	134 to 140* same as blood.
Potassium (mEq/L)	0 to 4 low
Calcium (mmol/L)	1.25 to 1.75 (<2.5 mEq/L) } same blood.
Magnesium (mmol/L)	0 to 0.75 (0 to 1.5 mEq/L) }
Chloride (mEq/L)	87 to 120 } same
Bicarbonate (mEq/L)	25 to 40 } increase
Glucose (g/dL)	0 to 0.2 } same

⚠ Common problems in CKD that dialysis helps:

Problem	How HD helps
Hyperkalemia	Diffusion of K^+ out of blood, (we keep the k^+ low in dialysate to move the k^+ of the blood by concentration drive)
Acidosis	Bicarbonate is added in dialysate (so bicarbonate moves to blood to correct the acidosis)
Fluid overload	Ultrafiltration removes fluid (for each kg the patient gains in the 2 days that he doesn't do dialysis we consider the kgs equivalent to the liters that have to be pulled out of the body , so for example 1kg = 1 liter that we have to get rid of)
Uremia	Removes toxins like urea and creatinine (you don't add anything just let the devices wash them out)

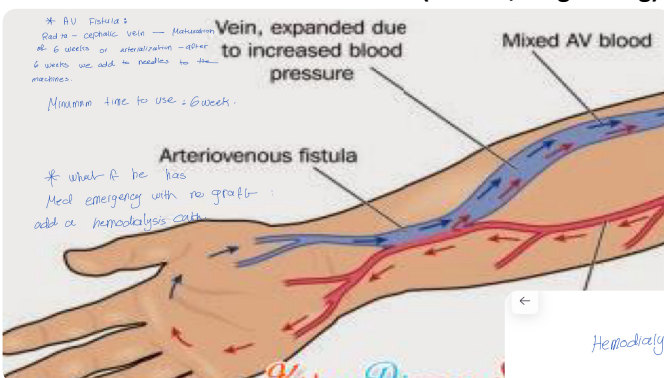
◆ Dialysis Access Types (vascular access):

Access	Time to Use (time to wait)	Notes
AV fistula, (direct surgical connection between the artery and the vein)	6 weeks	✅ Best access, from your own vessels
AV graft (synthetic tube to connect the artery and the vein)	2 weeks, for anastomosis	Synthetic tube connecting the artery to the vein , used if veins too small , so when fistulas can't be used
Central venous catheter (CVC)	3 weeks	❌ Last resort, high risk of infection , only if you have to

📌 If the patient has **no time** to wait (e.g. emergency), we use a **catheter** first.

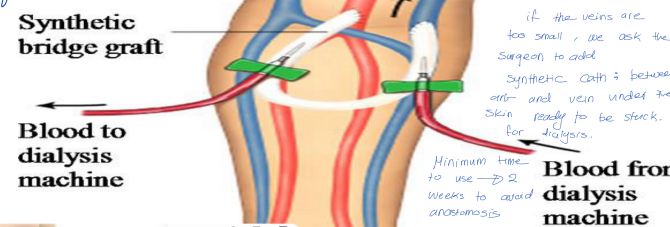
💡 Mnemonic:

Fistula = First choice (natural, long-lasting) **Graft** = Given (artificial, more risky) **Catheter** = Critical situation only

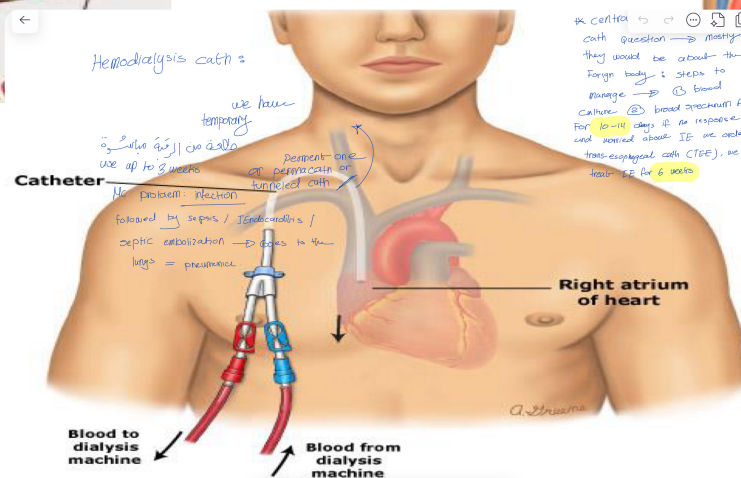


Fistula

Graft



Cath.



◆ Catheter Infection — Always Suspect It!

“HD patient with fever in ER... First question: What’s the dialysis access (fistula/ graft/ catheter) ?”

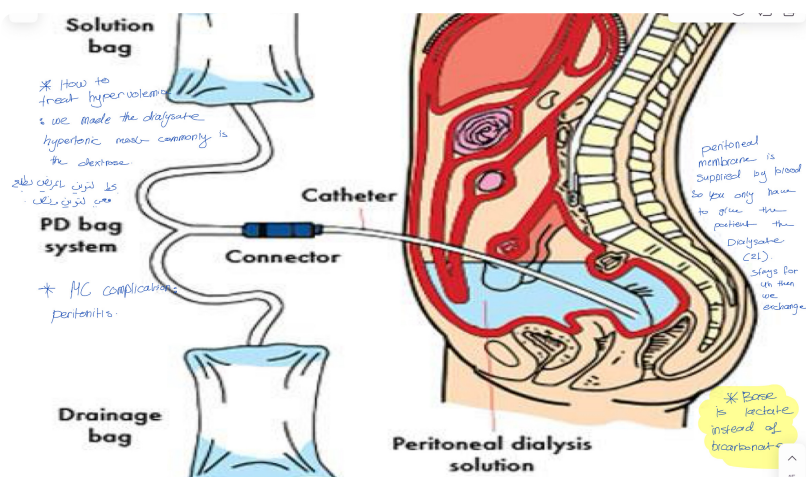
- If the patient has a **catheter**, always suspect **catheter infection** until proven otherwise
- Give **broad-spectrum antibiotics immediately**.
- Admit and monitor closely — these infections can cause **sepsis, pneumonia, emboli**.
- Note If you don’t suspect infective endocarditis treat with AB for **10-14 days** , but if you suspect it then treat for at least **6 weeks** and don’t forget to order TEE
- NOTE : you can tell if the graft or fistula is infected but its hard to guess in Cath because it might look perfectly normal but the patient might have IE

◆ Peritoneal Dialysis (PD)

➡ Uses the **peritoneal membrane** inside your belly as the filter. (used as a dialyzing surface)

💧 How it works:

- It mainly represents solute and fluid exchange across peritoneal membrane between the peritoneal capillary blood and the dialysis solution that is inserted into the peritoneal cavity
- Dialysate fluid is placed into the belly
- Waste and fluid pass from blood vessels → into the fluid
- Later, the fluid is drained
- This is repeated multiple times/day (CAPD) followed by overnight dwell or overnight (APD)-> its an auto device that does multiple exchanges overnight such as CCPD aka : continuous cycler peritoneal dialysis



Standard peritoneal dialysis solution

Volume (liters)	0.25, 0.5, 1, 1.5, 2.5, 3, 5, 6
Sodium (mEq/L)	132
Potassium (mEq/L)	0 to 2, mostly 0
Glucose (g/dL)	1.5, 2.5, 4, 25
Calcium (mEq/L)	2.5 to 3.5
Magnesium (mEq/L)	0.5 to 1.5
Lactate (mEq/L)	35 to 40

⚖️ Fluid removal in PD:

- Dialysate (we add 2 liters) contains **dextrose (sugar)** to pull fluid out by **osmosis** (**we made the dialysate hypertonic which is the dextrose so we could solve the problem of volume over load -> if we add 2l of dextrose we would get 2.5 fluid out**)
- **We solved the problem of hyperkalemia in the same way of hemodialysis**
- **We solved the problem of acidosis in the same way as well BUT we replaced bicarbonate with lactate**
- Osmotic agents allow net water removal by altering the osmotic pressure gradient between the peritoneal dialysis solution and plasma water.
- Stays for 4 hours
- Higher sugar % = more water removed

Available Dextrose %	Use
1.5%	Mild fluid removal
2.5%	Moderate
4.25%	Strong fluid removal

	Dextrose -5		Amino acid	Icodextrin
	Low Ca++	High Ca++		
Osmolality (mOsm/kg)	346, 396, and 485	346, 396, and 485	365	282
Molecular weight (Dalton)	182	182	100 to 200	20,000
Advantages	Well studied Most commonly used for a long time Side-effect profile well known to most of the nephrologists Allow the use of oral calcium-containing phosphate binders	Same as low-calcium solutions except it may help bringing up serum calcium in patients with low calcium levels	Can improve nutritional status in malnourished diabetic and/or patients with recurrent peritonitis	Sustained ultrafiltration for many hours Decreased solute absorption
Disadvantages	Short-lived ultrafiltration Metabolic complications like hyperinsulinemia, hyperglycemia, hyperlipidemia, and weight gain Can lead to low serum calcium and bone disease	Same as low calcium except it can limit the use of calcium-containing oral phosphate binders	Expensive May increase nitrogen waste product in blood May cause/worsen acidosis	Increases serum levels of maltose, maltotriose, and oligopolysaccharides
Indications	Commonly used, first-line PD solution in all patients unless special circumstances exist High serum phosphorus and normal to high serum calcium	Used in patients who have low calcium levels with low calcium-containing dialysis solutions	Malnourished diabetic patients or Malnourished patients with recurrent peritonitis	Patients who lose ultrafiltration In patients with automated PD situation during the dry day to achieve sustained UF and increased solute and fluid removal In diabetic patients

⚠ Complications of PD:

Problem	Notes
Peritonitis	Most common and serious
Exit-site infection	Around catheter skin
Catheter malfunction	Blocked or dislodged
Hernia, fluid leak	Due to pressure inside abdomen
Encapsulating peritoneal sclerosis	Late-stage, thick scarring

- Peritonitis remains a major complication of PD despite advances in equipment and aseptic technique.
- Peritonitis accounts for 15% to 35% of hospital admissions for these patients and is the major cause of catheter loss and technique failure resulting in transfer to hemodialysis
- Entry of bacteria into the catheter during an exchange procedure (**touch contamination**) is the most common source, but organisms can also track along the external surface of the catheter or migrate into the peritoneum from another abdominal viscus.
- Icodextrin-containing solutions can cause falsely elevated glucose levels. In patients using icodextrin, blood glucose monitoring must be done with glucose-specific methods to prevent falsely elevated levels and subsequent inappropriate treatment of presumed hyperglycemia.

🔍 Diagnosis of Peritonitis (in Peritoneal Dialysis)

Diagnosis requires the presence of any 2 of the following 3:

1. 🦠 Organisms on Gram stain or culture

- If we find **bacteria under the microscope** or later in a lab culture, it confirms infection.

2. ☁ Cloudy dialysis fluid

- White cell count **>100/mm³**
- More than **50% neutrophils** (a type of WBC)

3. 🔥 Symptoms/signs of peritoneal inflammation

- Things like **abdominal pain, fever, or tenderness**

📌 If any 2 of these are present, we **diagnose peritonitis** in PD patients.

🔍 **Confusing part: “if Ascites...cirrhosis... neutrophil count is 250”**

🔍 Clarification:

- In patients with **ascites** (fluid in the abdomen) from **cirrhosis**, peritonitis is diagnosed if neutrophils are **≥250/mm³**
- But in **peritoneal dialysis**, we only need **>100 WBCs and >50% neutrophils**. So the diagnostic criteria are **stricter in cirrhosis than PD**.

☁️ **“Cloudy dialysate effluent is almost invariably present”**

- The fluid drained from the abdomen will **almost always look cloudy** if the patient has peritonitis.

😞 **“Abdominal pain is present in about 80–95% of cases”**

- Most patients will feel **abdominal pain or discomfort**, but **some may not**, especially early.

🤒 **GI symptoms, chills, fever = in 25% of cases**

- Not all patients with peritonitis will have these.
- It’s important to **not wait** for fever or vomiting to suspect peritonitis.

👏 **Abdominal tenderness is seen in 75% of cases**

- Pressing on the belly will often show pain or guarding (**a protective reflex from inflammation**).

📖 **Causative Organisms of Peritonitis (Historical Trends)**

“Historically, **coagulase-negative staphylococci** were the most common cause”

- These are **skin bacteria** (like **Staph epidermidis**)
- Enter via **touch contamination** during PD bag exchanges

💡 **“Y-systems or flush-before-fill systems helped reduce this”**

- These newer tubing systems **reduce contact with outside air or hands**
- Resulted in fewer infections from coagulase-negative staph

😬 **“Now, more cases due to Staph aureus”**

- **Staph aureus** is more aggressive and dangerous than coagulase-negative types

💊 **Initial Antibiotic Treatment for PD-Associated Peritonitis**

✓ **Empiric treatment must cover:**

Type	Examples
Gram-positives	Vancomycin or 1st generation cephalosporin (e.g., cefazolin)
Gram-negatives	3rd generation cephalosporin (e.g., ceftriaxone) or aminoglycoside (e.g., gentamicin)

🌱 **Then tailor treatment** after culture/sensitivity results return.

🛑 **When to Remove the PD Catheter**

Remove the catheter if:

1. **Relapsing peritonitis** (keeps coming back)
2. **Refractory peritonitis** (doesn’t improve with treatment)
3. **Fungal or mycobacterial peritonitis** (hard to treat bugs)
4. **Associated intra-abdominal problem** (like abscess or ischemia)

⚠️ If peritonitis is caused by multiple bacteria (mixed Gram+/-):

- Be suspicious of a deeper problem:
- **Ischemic bowel**
- **Perforated diverticulitis**
- **Other abdominal source of infection**

💊 Prognosis and Treatment Outcome

- Most peritonitis cases **respond to outpatient antibiotics**
- Cure rate \approx **75%**
- But in **25%**, catheter has to be removed or patient switched to hemodialysis

👤 Special Consideration in Diabetics on PD

“Most DM patients will require insulin while they are on PD”


- **Even if they didn't need insulin before, they may now.**
- This is because:
- **Dextrose from dialysate is absorbed** into the bloodstream \rightarrow raises blood sugar
- Also causes **weight gain**

🪡 Insulin can be given:

- **IP (intra-peritoneal)** \rightarrow directly with the dialysis fluid
- **SC (subcutaneous)** \rightarrow standard injection under the skin

🪡 Kidney Transplantation: The Ultimate Treatment

“Kidney transplantation is the treatment of choice...”

-  Best long-term solution for ESRD
- Improves **survival, lifestyle**, and is **less expensive** over time compared to dialysis

⚠️ But not all patients can get a transplant:

❌ Exclusion Criteria:

- **Active infections**
- **Active cancer**
- **Ongoing substance abuse**
- **Reversible kidney failure** (like acute injury that may heal)
- **Uncontrolled psychiatric illness**
- **Poor medication compliance**
- **Very short life expectancy** (transplant would not benefit enough)

📅 When can patients be listed for transplant?

Country	When transplant listing is allowed
USA (UNOS)	When eGFR < 20 mL/min
Jordan / Europe	When eGFR < 15 mL/min (CKD Stage 5)

🧬 In Jordan:

- **Only living related donors** are allowed
- Requires:
- **ABO blood type matching**
- **HLA tissue matching** for immune compatibility

📌 Summary Tip:

Transplant = Best outcome PD = Home-based, gentle HD = Most used, especially in emergencies Fistula > Graft > Catheter Peritonitis = common but treatable — diagnose with **2 of 3**

60 yo lady with DM > 20 years, HTN > 20 years, progressive diabetic nephropathy with serum Cr as of today's clinic visit of 4.8 (eGFR around 9 ml/min). Na 138. K 4.9. HCO3 22. She still has good urine output. She denies any uremic symptoms and feels very good. She has left arm AVF placed 6 months ago and looks very good.

What is your best next step?

- A. Admit to the hospital and start dialysis soon.
- B. Since she has a good left arm AVF just call outpatient HD unit and start HD as outpatient.
- C. Continue close outpatient follow up (monthly visit with monthly lab).
- D. RTC every 3 months with routine lab.
- E. Refer her for kidney biopsy.

• no volume overload

Ⓒ no indications for dialysis

62 yo man with DM > 15 years, HTN > 15 years, progressive CKD secondary to DM + HTN presented for regular follow up visit. Cr is 5.2 (eGFR 7 ml/min). K is 5.2. HCO3 18. He complains of metallic taste, weakness and weight loss. He has left arm AVF in place placed 4 months ago and looks very good.

What is the best next step?

- A. Refer to the ER.
- B. Arrange to start HD ASAP.
- C. No urgent indications to start HD so continue monthly follow up visit.
- D. Refer for kidney biopsy and eye exam.
- E. RTC every 3 months with routine lab.

• He needs to start dialysis since CKD with uremic symptoms but not urgent

Ⓑ

35 yo man with ESRD on PD presented to the ER c/o RLQ abdominal pain and nausea for 2 days. PD fluid is clear. PD fluid cell count showed 30 WBCs.

What is the best next step?

- A. Admit for IV antibiotics for presumed peritonitis.
- B. D/C home on IP antibiotics after arranging with PD nurse.
- C. D/C home on oral antibiotics.
- D. D/C home on NSAIDs
- E. Rule out other etiologies for his presentation.

• no peritonitis
• Ⓔ

70 yo man presented to the ER c/o fever, chills and for one week. CXR showed bilateral pneumonia. BP 100/60 (baseline around 140s-150s/80s-90s). Lab s Cr of 5.0. K 7.0. EKG showed hyper-acute T waves.

What is the best next step?

- A. IV calcium gluconate.
- B. PO kayexalate.
- C. IV furosemide
- D. Arrange for HD catheter placement then dialysis
- E. IV antibiotics.

65 yo with ESRD on HD, DM > 20 years, HTN > 20 years. He was found dead this morning in his bed. Last HD was 2 days ago.

What is the most likely cause of his death?

- A. Hyperkalemia.
- B. Pulmonary edema.
- C. Acute MI.
- D. DKA.
- E. Uremic pericarditis.

Ⓒ he has factors of atherosclerosis