CRRT PRE - POST-Test

AKI & CRRT 2021

Question 1

- GP is a 47yo M with Hypertension (HTN), Coronary artery disease (CAD), Obstructive sleep apnea (OSA), Chronic kidney disease (CKD)(baseline creatinine 1.3 mg/dL), and obesity (Body Mass Index (BMI) 40) who presented with fever, hypotension, and hypoxemic respiratory failure secondary to COVID-19. Creatinine on admission was 2.1 mg/dL. He was initially resuscitated with fluids.
- On day 3 Nephrology is consulted for worsening AKI and volume overload unresponsive to high dose diuretics. On examination, he is intubated, sedated, paralyzed, and prone on Assist Control (AC)/Volume Control (VC)36/ Tidal volume 350 / FIO2 100 / PEEP 20. He is on inhaled epoprostenol and norepinephrine. Urine output the previous 24 h was 540 mL. Admission weight 110 kg.

Question 1 LABS

Blood urea nitrogen	55 mg/dL
Creatinine	4.4 mg/dL (baseline creatinine 1.3 mg/dL)
Electrolytes	
Sodium	138 mEq/L
Potassium	6.0 mEq/L
Chloride	105 mEq/L
Bicarbonate	20 mEq/L
ABG	7.21 / 58 / 45 on 100% FIO2
Creatinine phosphokinase	18,000 U/L
D-Dimer	2,318 ng/mL
MAS Ferritin	1995 ng/mL
Lactic acid	1.6 mmol/L
CBC	WBC 5,000 / Hct 30% / platelets 191,000
Urinalysis	SG 1.015, 2+ protein, 3+ blood, trace ketones, >25 RBCs/hpf

Question 1

Which of the following is the MOST appropriate next step? (Patient weight 110 kg)

A. Initiate CVVH with blood flow 200 mL/min, post filter replacement fluid 1500 mL/h and fluid removal rate 250 mL/h
B. Initiate CVVH with blood flow 180 mL/min, pre filter replacement fluid 1000 mL/h, post filter replacement fluid 1000 mL/h, and fluid removal rate 100 mL/h
C. Initiate CVVHD with blood flow 150 mL/min, dialysate rate 2800 mL/h and fluid removal rate 200 mL/h
D. Initiate CVVHDF with blood flow 250 mL/min, pre filter replacement fluid 2000 mL/h, dialysate 2500 mL/h, post filter replacement fluid 1500 mL/h, and fluid removal rate 300 mL/h

Answer: C

- In the ATN Study, there was no difference in mortality when comparing 6-days/week IHD with a target Kt/Vurea of 1.2-1.4/treatment in hemodynamically stable patients and CVVHDF at 35 mL/kg/h in hemodynamically unstable patients with 3-days/week IHD with a target Kt/Vurea of 1.2-1.4/treatment in hemodynamically stable patients and CVVHDF at 20 mL/kg/h in hemodynamically unstable patients.

- In the RENAL Study, CVVHDF at 40 mL/kg/h and CVVHDF at 25 mL/kg/h were also associated with similar mortality rates. Therefore the recommended minimum dose of CRRT is 20-25 mL/kg/h as long as the patient receives CRRT at least 20 hrs a day, or 25-30 mL/kg/h to account for time off.

- Option C provides CVVHD at a total effluent flow rate of 27 mL/kg/h (effluent rate of 3000 mL/h divided by patient's weight of 110 kg is equal to 27 mL/kg/h).

Incorrect Options

- A is incorrect by providing an inadequate dose of CRRT (effluent rate of 1750 mL/h / 110 kg = 16 mL/kg/h)
- B is incorrect since it provides an inadequate dose of CRRT (effluent rate of 2100 mL/h / 110 kg = 19 mL/kg/h).
- D is incorrect since current evidence with RCTs does not support high volume hemofiltration (HVHF) with effluent rate 57 mL/kg/h (6300 mL/h / 110 kg) for cytokine removal or rhabdomyolysis. Furthermore HVHF can cause harm with excessive removal of electrolytes, nutrients, and antibiotics.

Question 2

The patient in the previous case is started on CVVHDF with the following prescription:

Blood flow: 200 mL/min

Dialysate: 1800 mL/h

Post-filter replacement fluid: 1000 mL/h

Fluid removal: 100 mL/h

Weight: 110 kg

What portion of the effluent rate accounts for convective clearance?

A. 10 mL/kg/h
B. 16 mL/kg/h
C. 22 mL/kg/h
D. 26 mL/kg/h

Answer: A

Explanation:

- The total effluent dose for CVVHDF is the sum of the convective dose and diffusive dose in mL/h divided by the weight of the patient in kg.
  - The convective dose is the total UF rate which is the sum of the replacement fluid rate and net fluid removal rate.
  - The diffusive dose is the dialysate rate.
- In this question, the convective dose is the sum of the post-filter replacement fluid rate (1000 mL/h) and fluid removal rate (100 mL/h) divided by weight of 110 kg.
- Thus clearance by convection is 1100 mL/h divided by 110 kg or 10 mL/kg/h.

Incorrect Options

Explanation:

- B is incorrect because it represents the diffusive dose: dialysate rate (1800 mL/h) divided by 110 kg, which is 16 mL/kg/h.
- C does not represent diffusive, convective, or total effluent dose for this question and is a made up calculation.
- D is incorrect because it represents the total clearance or effluent dose (diffusive dose + convection dose) which is 2900 mL/h divided by weight (110 kg) or 26 mL/kg/h.

Question 3

Blood flow: 200 mL/min
Dialysate: 1800 mL/h
Post-filter replacement fluid: 1000 mL/h
Fluid removal: 200 mL/h

The patient in the previous case is on the above CRRT prescription. The ICU pharmacist pages you to ask you the "estimated" clearance being provided with CRRT. The patient is found to have Multi Drug Resistant (MDR) bacteria growing from a recent blood culture and the pharmacist wants to deliver his maintenance antibiotic dose appropriately. The protein binding for the antibiotic is 50%. The volume of distribution is low (30 L). The patient is anuric.

What is your answer to the ICU pharmacist?

A. Estimated clearance is < 15 mL/min
B. Estimated clearance is ~20-30 mL/min
C. Estimated clearance is ~40-50 mL/min
D. Estimated clearance is ~65-70 mL/min

Answer: B

- Clearance provided to the patient can be estimated by dividing the total effluent rate (mL/h) by 60 to convert it to mL/min.

- This is then multiplied by the sieving coeffiecient (SC) of the drug:
  - SC = 1-Protein Binding (PB)
  - 1 - 0.5 = 0.5

- C is the correct answer based on total effluent rate of 3000 mL/h for this patient and SC of 0.5: 3000/60 X 0.5 = 25 mL/min.

Question 4

The patient in the previous case clots his CRRT circuit several times. Therefore he is switched to citrate anticoagulation. He has a double lumen short-term dialysis catheter in his right internal jugular vein with the tip at the cavoatrial junction.

His CVVHDF prescription is changed as follows:

- Blood flow rate (BFR) = 100 mL/min
- Dialysate rate 1500 mL/h
- Post filter replacement fluid rate 1200 mL/h
- Fluid removal 300 mL/h
- His weight is 110 kg
- HCT 30%

Question 4

Blood flow: 100 mL/min
Dialysate: 1500 mL/h
Post-filter replacement fluid: 1200 mL/h
Fluid removal: 300 mL/h
Pt. Weight 110 kg
HCT 30%

The circuit is anticoagulated with A-CDA citrate infused via a port near the arterial access. His post filter iCa levels are < 0.35 mmol/L. The patient develops acute mental status changes and CRRT is disconnected for head CT. When the patient returns from CT, he is restarted on CRRT by the ICU nurse on the same prescription except with a blood flow of 200 mL/min. Four hours later the CRRT circuit clots.

What was the most likely cause of the premature clotting of the circuit?

A. Too short dialysis catheter length
B. Sub-therapeutic citrate dose
C. Increased filtration fraction
D. Inadequate dialysis dose

Answer: B

Explanation:

- Citrate concentration in the blood is dependent on blood flow. The optimal concentration of citrate in the blood associated with adequate anticoagulation is 3-5 mmol/L or post-filter iCa < 0.35 mmol/L. Increasing the blood flow rate decreases the citrate concentration in the blood, resulting in a sub-therapeutic citrate level and, therefore, clotting of the circuit.
- Option A is incorrect because the dialysis catheter is in the cavoatrial junction which is the appropriate location for providing adequate flows.
- Option C is incorrect because the filtration fraction (FF) is 14% and clotting of the circuit is associated with FF >20-25%. Increasing the blood flow decreases FF. FF = 1200 mL/h / (200 mL/min x 60 x 0.7) = 14%
- Option D is incorrect because dose does not impact clotting of the circuit. Furthermore the dose is adequate (effluent rate mL/h/kg) = 3000 mL/h / 110 kg = 27 mL/kg/h (adequate is between 20-25 mL/kg/h with guidelines suggesting 25-30 mL/kg/h to take into account time off CRRT device).

Question 5

A 50-year-old man is evaluated for AKI after undergoing coronary artery bypass grafting with mitral valve repair. During surgery, his BP fell transiently to 70/40 mm Hg, but the procedure was otherwise uneventful. His medical history includes stage 4 CKD, type 2 diabetes, and hypertension. The patient is intubated and ventilated, receiving 50% fraction of inspired oxygen. The blood pressure is 80/60 mm Hg while receiving an infusion of norepinephrine. Pulse oximetry is 92%. Cardiac examination is unremarkable, but lung examination reveals bibasilar crackles, and extremities have 2+ bilateral edema.

Clinical and laboratory data include the following:

	Admission	Day 3	Reference Range
Weight	75 kg	80 kg	Varies
Urine output	1820 mL/d	460 mL/d	Varies
Potassium	4.7 mEq/L	5.5	3.5–5.0
Blood urea nitrogen (BUN)	41 mg/dL	98	8–20
Creatinine	3 mg/dL	6	0.7–1.3

Question 5

Continuous venovenous hemofiltration (CVVH) is begun with blood flow of 200 mL/min, ultrafiltration rate 50 mL/h, and 1 L/h pre-filter and 1 L/h postfilter replacement fluid. The replacement fluid contains 35 mEq/L bicarbonate and 2 mEq/L potassium.

At day 5, the patient's BP remains 80/60 mm Hg on the same rate of norepinephrine infusion, and the right leg is mottled with decreased pulses. His potassium is 5.6 mEq/L, BUN 28 mg/dL, and creatine kinase 25,000 IU.

Which of the following is the next BEST step in management of his renal replacement therapy?

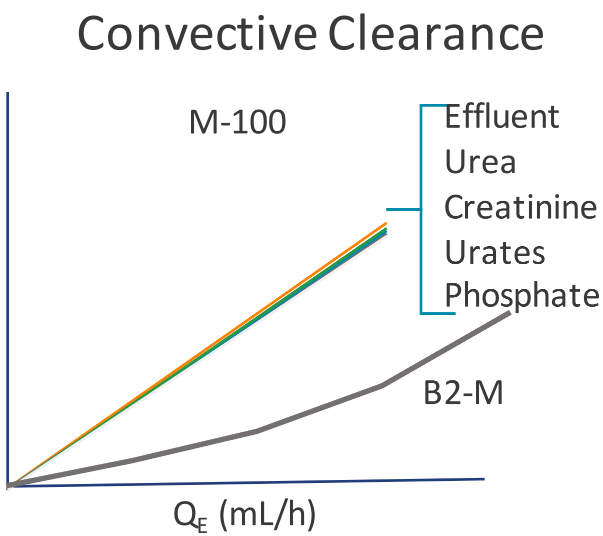
A. Change replacement fluid to 0 L/h prefilter and 2 L/h postfilter
B. Increase blood flow to 300 mL/min
C. Increase ultrafiltration rate to 150 mL/h
D. Convert to continuous venovenous hemodialysis with dialysate flow 2 L/h
E. Change replacement fluid to 2 L/h prefilter and 2 L/h postfilter

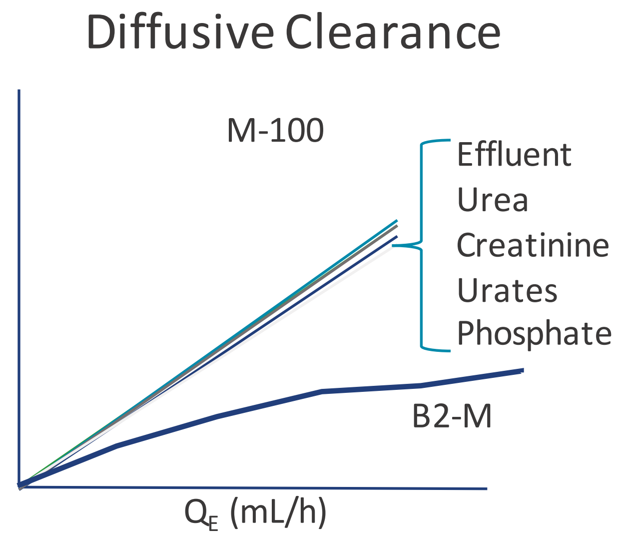
Answer: E

- Clearance is dependent on the rate of effluent and is improved by anything that increases effluent generation rate.
- Answer E has the highest effluent rate of 4 L/h

- Incorrect Options
  - A: Partitioning replacement fluid (RF) in CVVH may be done pre-filter to prevent clotting or post-filter to theoretically improve clearance. However clearance would be minimally improved when compared to E Patient has insufficient clearance.
  - B: Given the slow effluent rate compared to blood flow rate, complete equilibration of small solute concentration between blood and replacement fluid occurs. Thus, increasing blood flow to 300 mL/min would not improve clearance significantly.
  - C: The bulk of the effluent is composed of RF (2 L/h total), whereas the ultrafiltrate (fluid removal) contributes relatively little (only 50 mL/h), so increasing ultrafiltration rate to 150 mL/h would not significantly improve clearance.
  - D: Changing from CVVH to CVVHD with the same rate of dialysate and ultrafiltration would not affect clearance significantly

Convection vs. Diffusion

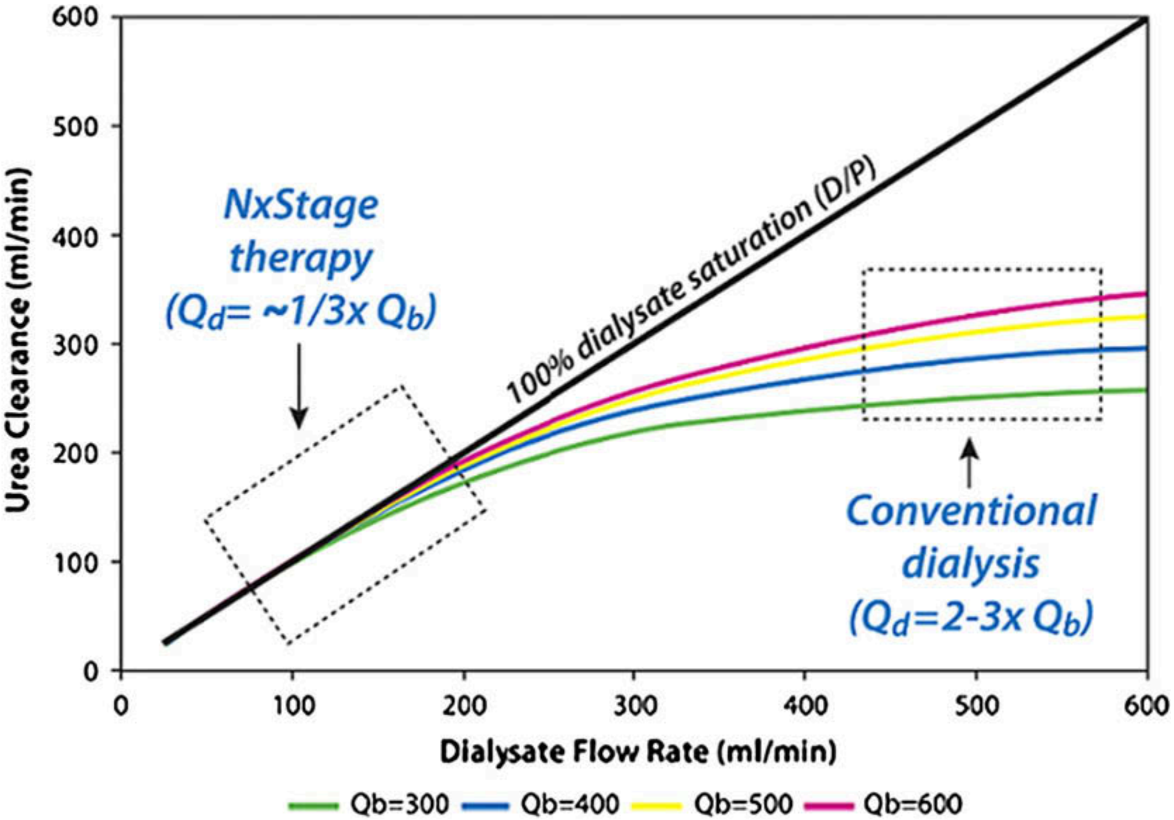




- Clearance is proportional to effluent rate for small molecular weight solutes
- Increasing effluent rate increases solute clearance
- CVVH clearance = CVVHD clearance for same effluent rates for small molecular weight solutes

Brunet et al. Am J Kidney Dis 1999;34:486-492

Blood Flow Rate vs. Dialysate Flow Rate

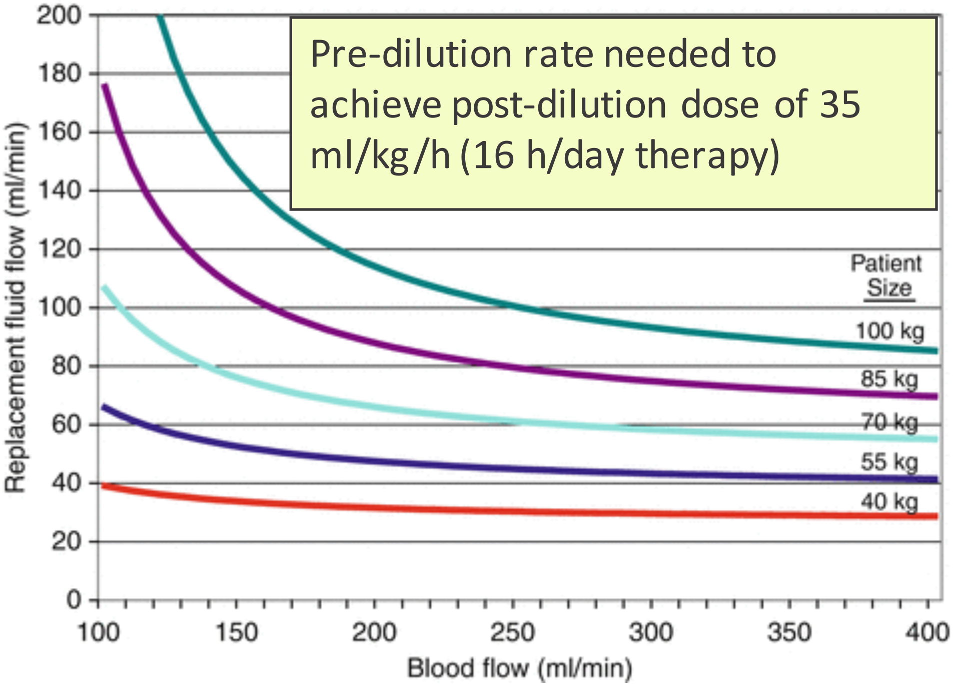


- Q_B should be ≥ 3 X Q_D
- For dialysate flow rate of 4 L /h, blood flow rate should be 200 ml/min
- Allows for complete saturation of dialysate and preserves linear relationship of dialysate rate and small solute clearance

Leypoldt J et at. Clearances for Small Solutes at Low Dialysate Flow Rates. Poster Presented ASN 2005

Blood Flow Rate vs. Pre-filter Replacement Fluid Rate

Effect of Q_B on Targeted Dose Delivery in Pre-Dilution CVVH



- For Pre-filter CVVH, Q_B should be ≥ 6 X Q_R (optimizes efficiency of solute clearance)
- For Pre-filter Fluid of 2 L/h, Blood Flow Rate should be about 200 ml/min
- Dilution factor = Plasma flow / (Plasma flow + Pre-filter RF) and should be ≥ 0.8

Clark WR et al. Dose determinants in continuous renal replacement therapy. Artif Organs. 2003

Question 6

A 47 year old 60 kg female with decompensated cirrhosis and chronic hyponatremia develops septic shock and AKI. She is started on CVVHD at dose of 25 mL/kg/hr and blood flow rate is 150 mL/min. Fluid removal is 0. Dialysate has the following composition (5 L bag): Na 140 meq/L , K 4 meq/L, Bicarb 35 meq/L , Ca 3 meq/L

Patient Labs:
Sodium 110 meq/L, Chloride 90 meq/L, Potassium 5.5 meq/L, Bicarbonate 16 meq/L, BUN 90 mg/dL, Creatinine 4.5 mg/dL, glucose 240 mg/dL

Which of the following management strategies is **MOST** appropriate for increasing serum sodium by no more than 6-8 meq/L in 24 hours?

A. Remove 500 mL of fluid from 5L CRRT solution bag and replace with 500 mL of sterile water
B. Decrease blood flow to 100 mL/min
C. Add 300 mL of sterile water to 5 L bag of dialysate fluid
D. Add D5W as post-filter RF at 250 mL/hr

Answer: D

- Correct Answer is D. D5W can be used as post-filter RF to slowly correct patients who have hyponatremia:
  D5W rate = [(140 - target Na) / 140] x desired clearance. Desired clearance is 25 mL/kg/hr X 60 = 1500 mL/hr (1.5 L/hr)
  D5W rate = [(140 – 116) / 140] x 1.5 = .257 or about 250 mL/hr
- A is incorrect. $Volume\ to\ exchange\ = V_i - \frac{desired\ [Na^+]}{initial\ [Na^+]} \times V_i$
  5 L – 116/140 x 5 L = 0.857 L or about 900 mL not 500. 500 mL will lead to a too high sodium concentration of 126 meq/L in the bag.
- B is incorrect since decreasing the blood flow will have little effect on serum sodium changes.
- C is incorrect. 5L bag X 140 meq/L = 700 meq. Adding 300 mL sterile water would make the sodium concentration 700 meq Na / 5.3 L = 132 meq/L

Question 7

A 63 YO M was admitted to the hospital with septic shock with hypotension requiring pressors and has minimal urine output (80ml/day). During an employment physical for the Daily Planet last month his Cr was 0.8 mg/dl. He was diagnosed with rhabdomyolysis, AKI, shock liver and DIC.. A right IJ quinton catheter was placed and CRRT was started. Admission Wt: 90 kg, Hct 30%.

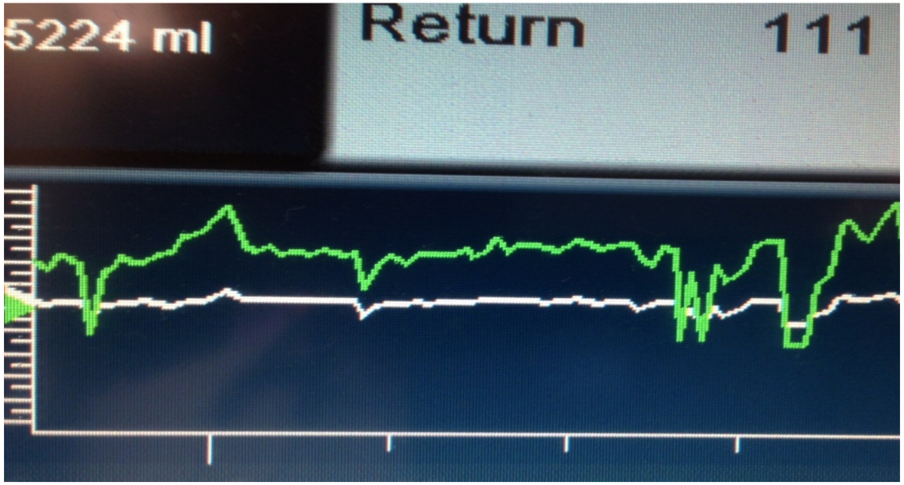
CRRT Prescription:

Machine: Prismaflex
Anticoagulation: none
Mode: CVVHDF
Dose: 25 ml/kg/h
Blood flow rate: 200 ml/min
Post filter replacement fluid: 2.5 L Prismasol(BGK2) all post filter
Hourly UF to maintain at even balance 500 ml/h

During rounds the next day the nurse tells you that the filter clotted 3 times in the last 24 hours.

Question 7

- These are the pressures:
- Access pressure: -70 mmHg (-50 to -150 mmHg)
- Return pressure: 90 mmHg (50 to 150 mmHg)
- Filter pressure: 350 mmHg (100 to 250 mmHg)



Pressure Drop: 110 mmHg **TMP: 210 mmHg**

What is the cause of the clotting?

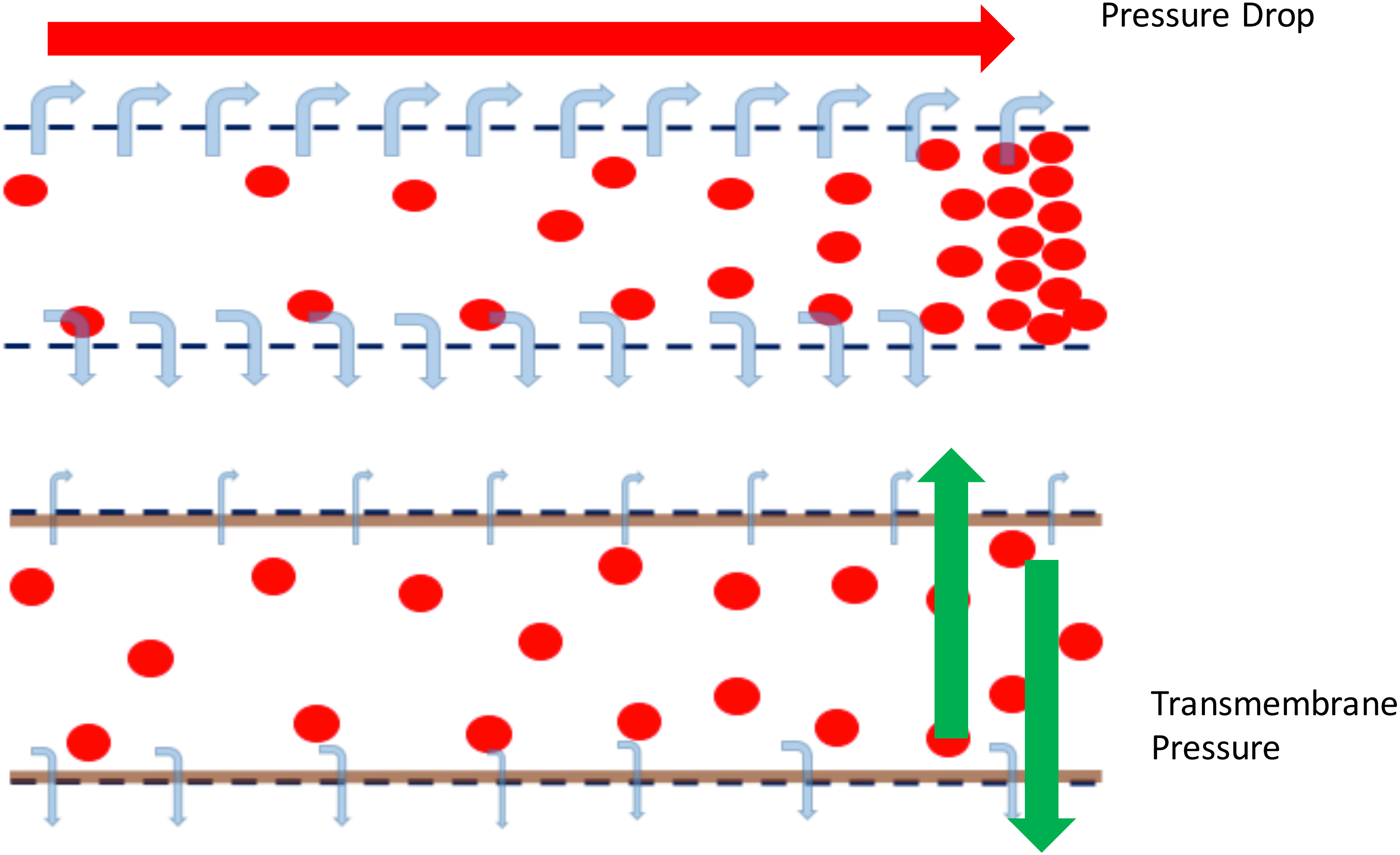
A. Clogging of the filter
B. Clotting of the filter
C. Problem with the dialysis access

Answer A

High filter pressure

Increase pressure drop (>150mmHg): Clotting

Increase in TMP (>150mmHg): Clogging



Question 7

Identify and manage CRRT machine problems (Prismaflex)

Problem	Access pressure	Venous pressure	Filter pressure	Pressure drop	TMP	Effluent pressure
Access line	**Increased > -150 mmHg**	Normal pressures	Normal pressures	Normal pressures Can increase with time	Normal pressures	Normal pressures
Return line	Normal pressures	**Increased > 150 mmHg**	**Increased >250 mmHg**	Normal pressures	Normal pressures	Normal pressures
Clotting	Normal pressures	Normal pressures	**Increased >250 mmHg**	**Increased (> 100 mmHg from starting pressure)**	Normal pressures	Normal pressures
Clogging	Normal pressures	Normal pressures	**Increased >250 mmHg**	Normal pressures	**Increased (> 100 mmHg from starting pressure)**	**Highly negative > -150 mmHg**

Question 7

Identify and manage CRRT machine problems (NxStage)

Problem	Access pressure	Venous pressure	Chamber pressure	Effluent pressure
Access line	**Increased > -150 mmHg**	Normal pressures	Normal pressures	Normal pressures
Return line	Normal pressures	**Increased > 150 mmHg**	**Increased >250 mmHg**	Normal pressures
Clotting	Normal pressures	Normal pressures	**Increased >250 mmHg**	Normal pressures
Clogging	Normal pressures	Normal pressures	**Increased >250 mmHg**	**Highly negative > -150 mmHg**