CRRT Fundamentals
Pre- and Post- Test Answers

AKI & CRRT 2017

Practice Based Learning in CRRT

Question 1

A 72-year-old man with HTN presents to the ED with slurred speech, headache and weakness after falling at home. He endorses a 3 day history of decreased oral intake, dizziness, fever, and yellow sputum production. A CT scan of the head demonstrates moderate edema associated with an intracranial hemorrhage and mass effect. Prior to admission to the ICU, he develops PEA arrest and undergoes successful CPR. He is transferred to the ICU on a norepinephrine infusion after receiving 6L of IV fluids. Nephrology is consulted 6 hours later for anuric AKI and volume overload. He is mechanically ventilated with FIO_2 70% and remains on a norepinephrine infusion. He is febrile with elevated WBC count and mild thrombocytopenia. Chest radiograph is read as pneumonia with superimposed edema. Renal ultrasound is normal. Other pertinent laboratory studies:

Blood urea nitrogen	67 mg/dL
Creatinine	4.3 mg/dL (baseline creatinine 1.4 mg/dL)
Electrolytes	
Sodium	132 mEq/L
Potassium	6.4 mEq/L
Chloride	95 mEq/L
Bicarbonate	16 mEq/L
Lactic acid	5.2 mmol/L
Serum pH	7.22
Urinalysis	Specific gravity 1.010; trace blood; 0-3 erythrocytes/hpf; multiple granular casts and tubular epithelial cells

Question 1

The nephrologist decides to initiate the patient on CRRT. The intensivist asks the nephrologist the reason for initiating CRRT instead of intermittent hemodialysis (IHD).

Which of the following is the strongest evidence for supporting CRRT?

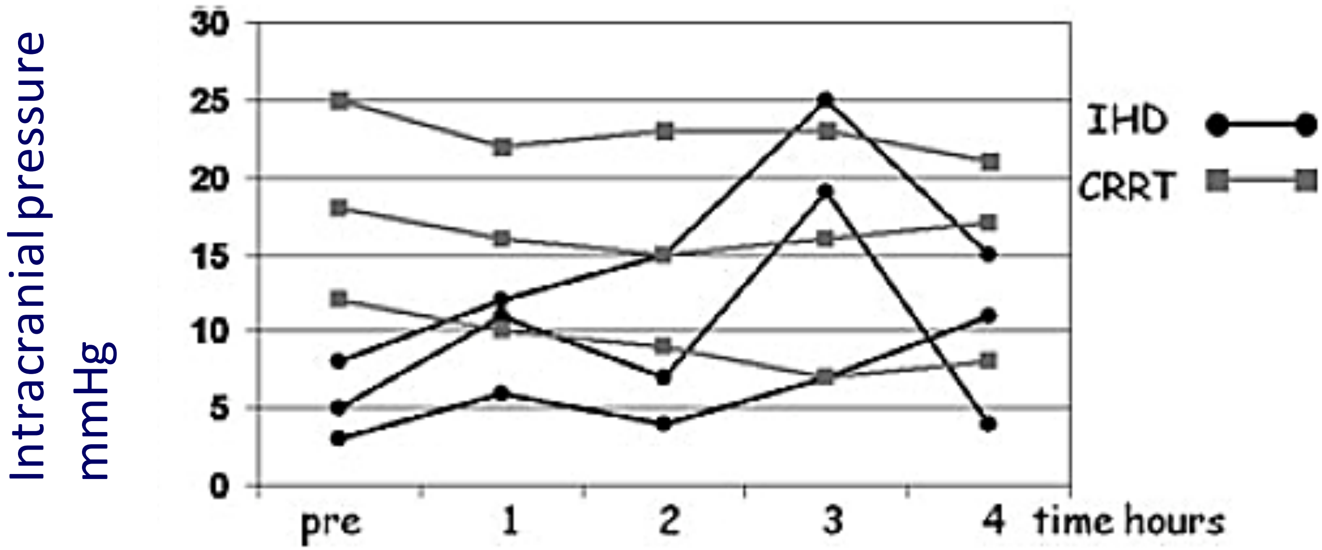
A. CRRT results in better renal recovery.
B. CRRT improves survival in hemodynamically unstable patients.
C. CRRT causes less intracranial pressure shifts in patients with acute brain injury.
D. CRRT improves patient survival in sepsis-mediated AKI.
E. CRRT reduces patient ventilator days through more effective volume removal.

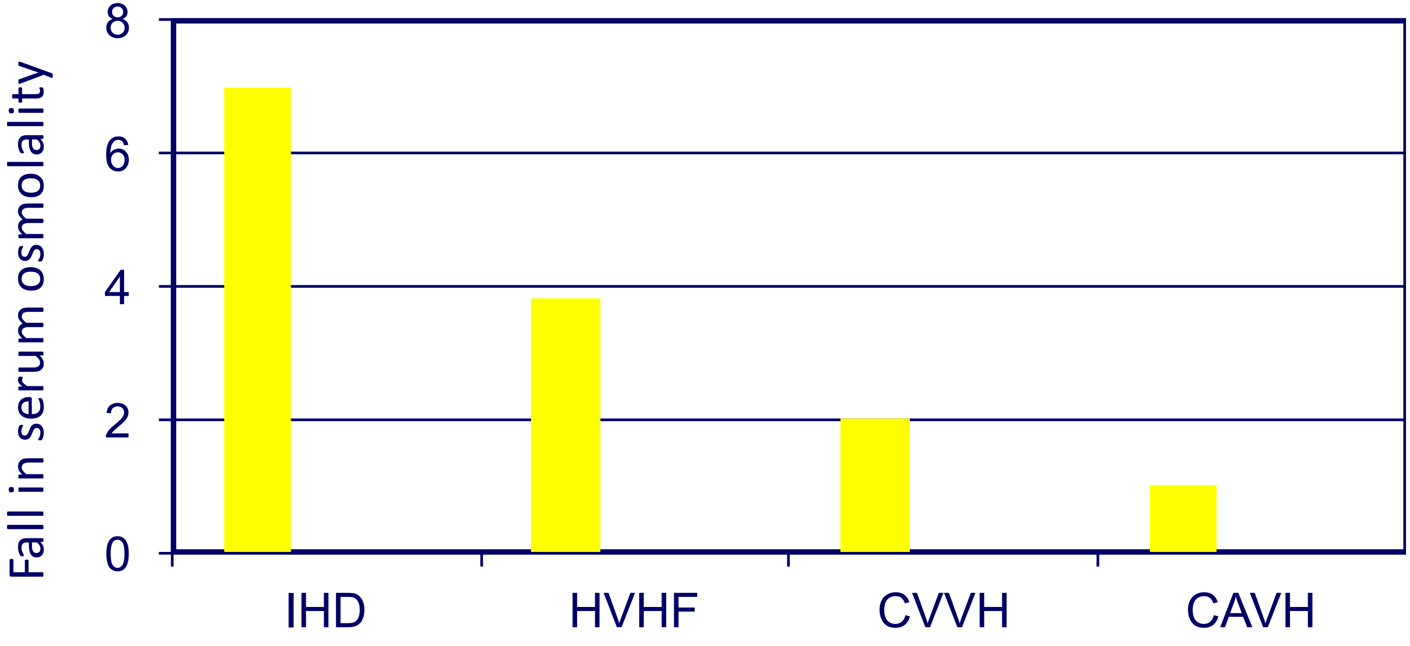
Question 1

In a patient with acute brain injury, IHD may worsen neurological status by compromising cerebral perfusion pressure. In patients with cerebral edema, continuous therapy is recommended in order to prevent decreased cerebral blood flow. CRRT will also prevent sudden changes in serum osmolality. Both hypotension and disequilibrium can be avoided by the slow progressive removal of fluids and solutes that occurs during CRRT.

Option A is incorrect because insufficient evidence exists regarding the superiority of CRRT over IHD with regards to renal functional recovery. The studies are mainly observational and no randomized trial has demonstrated CRRT improves renal recovery when compared with IHD. **Option B is incorrect** because no RCTs have shown CRRT improves survival in hemodynamically unstable patients when compared with IHD. **Option D is incorrect** because despite the notion that CRRT with convective therapy can potentially remove cytokines and other inflammatory mediators in septic patients, RCTs have not demonstrated a benefit of convective therapy (CVVH) when compared to diffusive therapy (CVVHD) in septic patients with AKI. RCTs comparing high volume hemofiltration (HVHF) (total effluent or ultrafiltration rates ≥ 50 ml/kg/hr) with standard dose CVVH (20-25 ml/kg/hr) have also not demonstrated a survival benefit, nor improved organ dysfunction. Furthermore HVHF has been shown to cause excessive loss of electrolytes, nutrients, and antibiotics. Therefore, at this time, HVHF for removal of cytokines or septic mediators is not supported. **Option E** is incorrect because no studies have shown CRRT decreases ventilator days.

CRRT in Management of ICP





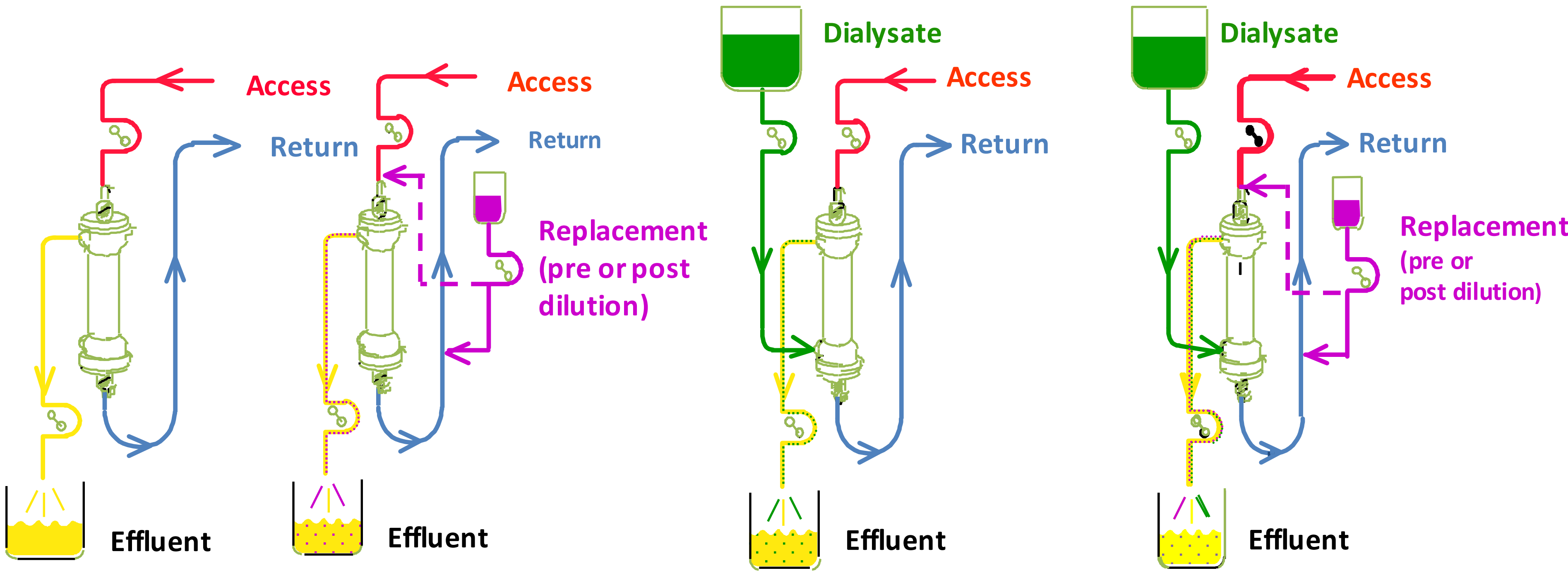
Davenport A. Sem Dialysis. 2009

Question 2

Which ONE of the following statements regarding CRRT modalities is **MOST** correct?

A. SCUF removes plasma water mainly by ultrafiltration and requires replacement fluid.
B. CVVH removes solutes and plasma water mainly by convection and ultrafiltration and requires replacement fluid.
C. CVVHD removes solutes and plasma water mainly by diffusion and ultrafiltration and requires replacement fluid.
D. CVVHDF removes solutes and plasma water mainly by absorption, diffusion, and ultrafiltration and requires both replacement fluid and a dialysate.

CRRT Modalities



SCUF

No solute clearance;

Used for fluid removal

CVVH

Solute clearance: convection;

Operative fluid: RF

CVVHD

Solute clearance: diffusion;

Operative fluid: dialysate

CVVHDF

Solute clearance: diffusion & convection;

Operative fluids: RF & dialysate

Question 3

Which ONE of the following statements regarding solute clearance in CRRT is **MOST** correct?

A. The sieving coefficient for urea decreases over time.

B. Solute clearance is inversely proportional to the effluent flow rate.

C. Small solute clearance is equivalent for CVVHD and pre-dilution CVVH if similar effluent and ultrafiltration rates are used

D. The sieving coefficient for small molecular weight molecules such as creatinine is zero

E. Diffusive solute clearance is optimized with dialysate/blood flow ratio > 0.3.

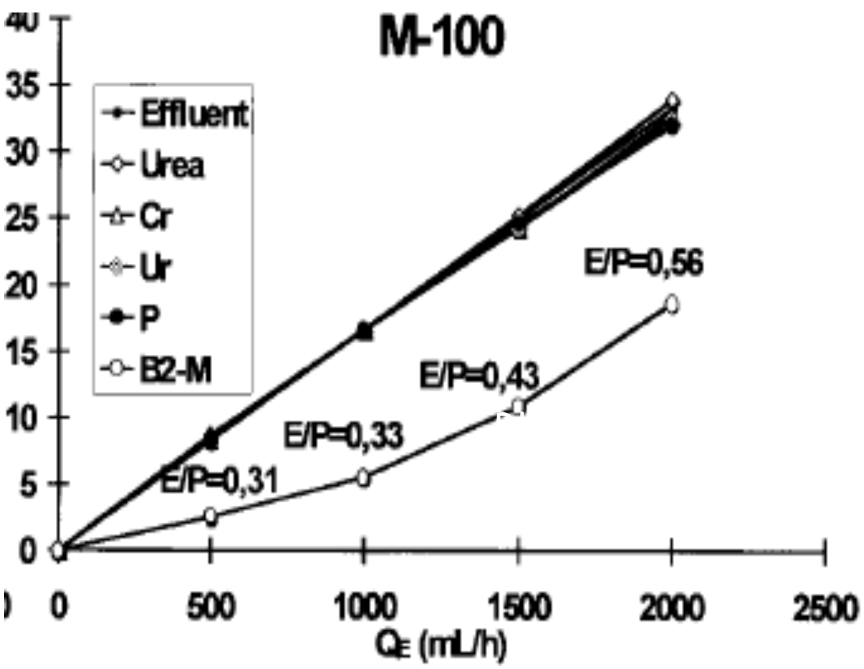
Question 3

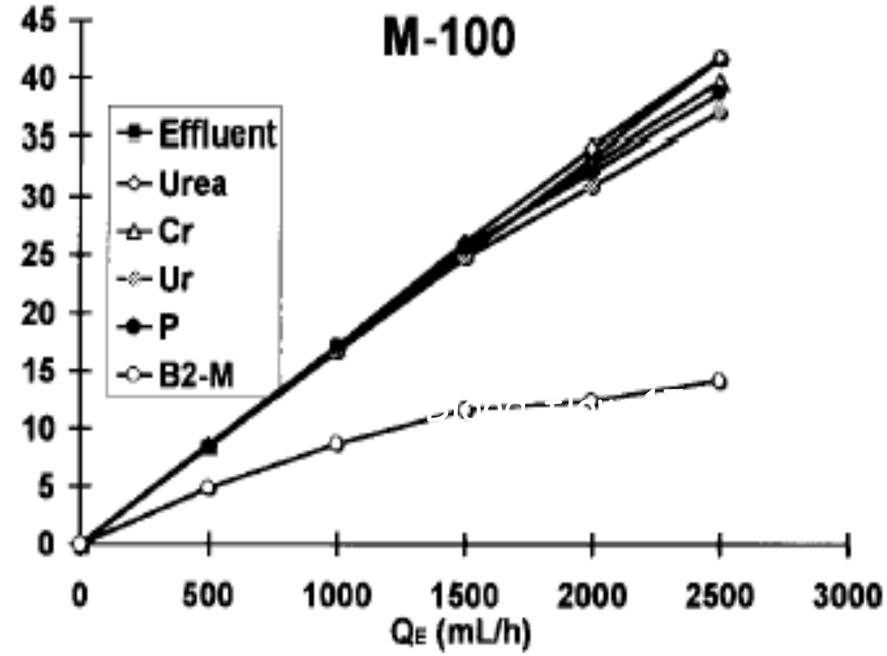
- The correct answer is A. Even though the sieving coefficient for urea is 1, the sieving coefficient for urea decreases on a daily basis due to protein layering on the membrane.
- B is incorrect because solute clearance is **directly** proportional to the effluent flow rate.
- C is incorrect because small solute clearance is equivalent for CVVHD and **POST**-dilution CVVH (not pre-dilution) if similar effluent and ultrafiltration rates are used.
- D is incorrect because the sieving coefficient for small molecular weight molecules such as urea is 1.
- E is incorrect because the dialysate is not completely saturated when the dialysate/blood flow ratio > 0.3 and the linear relationship of increasing the dialysate to increase solute clearance is lost.

Calculating Solute Clearance

- Generic Clearance =
  - Mass removal rate / Blood concentration
  - Effluent flow rate x Effluent concentration/Blood concentration
- $K = Q_E \times C_E/C_B$
- Using urea as solute
  - $Q_E << Q_B$ (17-50 ml/min vs. 150-200 ml/min)
  - Equilibrium achieved ($C_E = C_B$)
- $C_E/C_B = \sigma$ = Sieving Coefficient
- Sieving coefficients for small MW molecules such as urea = 1

Effect of Convection vs. Diffusion on Solute Clearance





Key points

•Clearance ∝ Effluent Rate for small molecular weight particles

•Increasing effluent rate increases solute clearance

•CVVH (post-filter RF) clearance = CVVHD clearance for same effluent rates for small molecular weight particles

Question 4

An 100 kg patient is on the following CRRT Parameters:

CVVHDF
Blood Flow 100 ml/min
Pre-Filter Replacement Fluid 1800 ml/hr
Dialysate 1000 ml/hr
Post-Filter Replacement Fluid 200 ml/hr
Fluid Removal 250 ml/hr

His HCT is 25%.

What is the CRRT prescribed dose?

A. 19 ml/kg/hr
B. 28 ml/kg/hr
C. 33 ml/kg/hr
D. 49 ml/kg/hr

Dose = effluent rate / patient weight =
1800 + 1000 + 200 + 250 / 100 kg = 32.5 ml/kg/hr

Question 5

What is the CRRT circuit filtration fraction for the patient in question 5?

A. 24%
B. 36%
C. 50%
D. 72%

Filtration Fraction = Net ultrafiltration rate (RF + Fluid removal) / plasma flow rate = 2250 ml / [((100 ml/min x 60 min)(1-0.25)) + 1800 ml/hr] = 36%

Question 6

A 70 kg male is placed on CVVH with a total ultrafiltration rate (effluent rate) of 20 ml/kg/hr. The Blood Flow Rate is 200 ml/min and the Replacement Fluid is administered Post Filter. The patient's potassium is 5.0 meq/L.

What will be the percent change in rate of potassium clearance with increasing the CVVH dose to 25 ml/kg/hr?

A. 10%
B. 15%
C. 20%
D. 25%
E. 30%

Question 6

- The K will be removed 25% faster (There is a 25% change from 20 to 25 ml/kg/hr)
- An increase in dose of 5 ml/kg/hr over 20 ml/kg/hr is a 25% change
- 5 ml/kg/hr divided by 20 ml/kg/hr is 0.25

Question 7

A 51 year old homeless man is admitted to the MICU with sepsis and multi-lobar pneumonia requiring mechanical ventilation. Blood and sputum cultures are positive for E. coli. Nephrology is consulted on hospital day 3 for AKI.

He is mechanically ventilated and requires 75% FIO_2. He is febrile, heart rate 122 beats/minute, blood pressure 95/60 mmHg on norepinephrine and vasopressin infusions, and CVP 16 cm H_2O. Pulse pressure variation using hemodynamic monitoring is 8%. Examination of the chest reveals coarse breath sounds and inspiratory crackles throughout both lungs. He has generalized anasarca. He has made 250 mL of urine over the last 24 hours; he had made 500 mL over the preceding 24 hrs. His current weight is 80 kg (admission weight 71 kg).

Labs:

Blood urea nitrogen	105 mg/dL
Creatinine	5.2 mg/dL (admit creatinine 2.1 mg/dL)
Electrolytes	
Sodium	135 mEq/L
Potassium	6.2 mEq/L
Chloride	97 mEq/L
Bicarbonate	14 mEq/L
Phosphorous	6.9 mg/dL
Creatinine phosphokinase	20,200 U/L
Serum pH	7.28
Urinalysis	4+ blood; 0-1 erythrocytes/hpf; 0-2 white blood cells/hpf; numerous granular casts

Question 7

Which of the following is the **MOST** appropriate next step in this patient's management?

A. Start a continuous infusion of intravenous sodium bicarbonate.
B. Start a continuous infusion of intravenous furosemide.
C. Initiate continuous venovenous hemofiltration (CVVH) with total ultrafiltration (effluent) rate of 1200 ml/hr.
D. Initiate high volume hemofiltration (HVHF) with total ultrafiltration (effluent) rate of 5600 ml/hr.
E. Initiate continuous venovenous hemodialysis (CVVHD) with effluent rate of 2000 ml/hr.

Question 7

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/hour 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/hr in hemodynamically unstable patients. In the RENAL Study, CVVHDF at 40 mL/kg/hr and CVVHDF at 25 mL/kg/hr were also associated with similar mortality rates. Therefore the recommended minimum dose of CRRT is 20-25 mL/kg/hr as long as the patient receives CRRT at least 20 hrs a day. Option D provides CVVHDF at a total effluent flow rate of between 20 and 25 mL/kg/hr (effluent rate of 2000 ml/hr divided by patient's weight of 80 kg is equal to 25 mL/kg/hr), which is what is currently acceptable.

Option A is incorrect because a bicarbonate infusion will not treat the hyperkalemia or alleviate the AKI. Furthermore, it will add extra volume to a patient who is already volume overloaded based on exam and hemodynamic monitoring with PPV of only 8%. **Option B is incorrect** since lasix will not treat the electrolyte abnormalities. **Option C is incorrect** by providing an inadequate dose of CRRT (effluent rate of 15 ml/kg/hr). **Option D is incorrect** since current evidence with randomized controlled trials does not support high volume hemofiltration (HVHF) for sepsis. Furthermore HVHF can cause harm with excessive removal of electrolytes, nutrients, and antibiotics.

Question 8

A 43 yo F (current weight 90 kg) is admitted to the MICU with severe shock, acute respiratory failure, and AKI. She is mechanically ventilated and on multiple vasopressors. She has bilateral infiltrates on CXR and was started on vancomycin and cefepime in the ED. Shortly after admission to the ICU she is initiated on CRRT for severe acidemia with the following settings: CVVHDF, blood flow rate 150 ml/min, ACD-A citrate 250 ml/hr, dialysate flow rate 2000 ml/hr, and post-filter replacement fluid rate 1250 ml/hr with fluid removal target to keep ins equal to outs.

Which of the following is the **MOST** correct statement in setting of starting CRRT?

A. Adjust antibiotic dosing for estimated creatinine clearance < 10 ml/min in setting of AKI
B. Adjust antibiotic dosing for estimated creatinine clearance of 35-40 ml/min
C. No adjustment to antibiotic dosing needed in patients with CRRT
D. Adjust antibiotic dosing to estimated creatinine clearance of > 50-60 ml/min
E. Change to PIRRT as antibiotic dosing is more readily known in PIRRT

Question 8

ANSWER: D
Estimated creatinine clearance is 3500 ml/hr (effluent) / 60 min = 58 ml/min

A – Incorrect because CRRT will clear the antibiotics
B – Incorrect because this is the current weight-based CRRT "dose" but actual ml/min clearance is higher than the CRRT weight-based dose. Weight-based dose is 3500 ml/hr / 90 kg = 39 ml/kg/hr
C – Incorrect
E – Incorrect because antibiotic dosing in PIRRT is entirely uncertain

Question 9

A 79 year-old critically ill male with AKI is placed on CVVH with post filter replacement fluid. He has a hematocrit of 30% and weighs 68 kg.

Blood flow rate	100 ml/min
Post-filter replacement fluid rate	1200 ml/hr
Fluid removal rate	300 ml/hr
Anticoagulation	4% trisodium citrate (TSC) delivered through a y-connector at the arterial access external to the CRRT device at 180 ml/hr

His post-filter iCa levels are < 0.30 mmol/L. His access is a 13 French 15 cm double lumen catheter inserted in Right IJ.

Which of the following management options **BEST** decreases the chance of further filter clotting?

A. Switching to heparin anticoagulation
B. Increasing the replacement fluid rate
C. Increasing the blood flow rate
D. Increasing the citrate rate
E. Changing his dialysis access

Filtration Fraction (FF) = $Q_{totalUF} / Q_P$

(1200 + 300 + 180) / [(6000 X 0.7) + 180] =

38.4%

Filter clotting with FF > 20-25%

Question 10

A 47 year old 60 kg female with DM, decompensated cirrhosis and chronic hyponatremia develops spontaneous bacterial peritonitis and anuric AKI. She is on norepinephrine, octreotide, midodrine, albumin, and antibiotics. She is started on CVVH with Post Filter Replacement Fluid. CVVH blood flow rate is 100 ml/min; Replacement Fluid rate is 1500 ml/hr. The Replacement Fluid 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 119 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 270 mg/dL, total bilirubin 15 mg/dL, INR 2.7, platelets 30,000, hgb 8 g/dL

Which of the following management strategies is **MOST** appropriate for decreasing the rate of sodium rise to no more than 8-12 mEq/L day on CRRT?

A. Start an intravenous infusion of D5W at 100 ml/hr
B. Add 200 ml of sterile water to 5 L bag of replacement fluid
C. Start intravenous DDAVP
D. Add 500 ml of sterile water to 5 L bag of replacement fluid
E. Decrease Replacement Fluid rate to 1000 ml/hr

Question 10

Correct Answer is D. Adding 500 ml of sterile water decreases sodium concentration in bag to 127 mEq/L which is a less than 10 mEq/L change from patient's sodium concentration of 119 mEq/L

- Sodium content in 5 L: 140 mEq/L X 5 L = 700 mEq of Na
- If you had 0.5 L of sterile water, total bag volume is 5.5 L
- Concentration of sodium: 700 mEq / 5.5 L = 127 mEq/L

A. D5W at 100 ml/hr would not be enough free water to decrease rate of sodium rise from CRRT and will result in worsening blood sugar control in a diabetic patient.
B. Sodium concentration when 200 ml added to CRRT bag = 700 mEq Na / 5.2 L = 134 mEq/L, which is a 15 mEq increase in sodium from baseline.
C. DDAVP will not work in anuric AKI
E. This will help decrease sodium delivery to patient but will provide an in adequate dose of dialysis to patient (1000 ml/hr / 60 kg = 17 ml/kg/hr). Although this will decrease the rate of sodium rise, it likely will still result in sodium increase of > 10 mEq/L in 24 hrs.