Preserving Circuit Patency in CRRT

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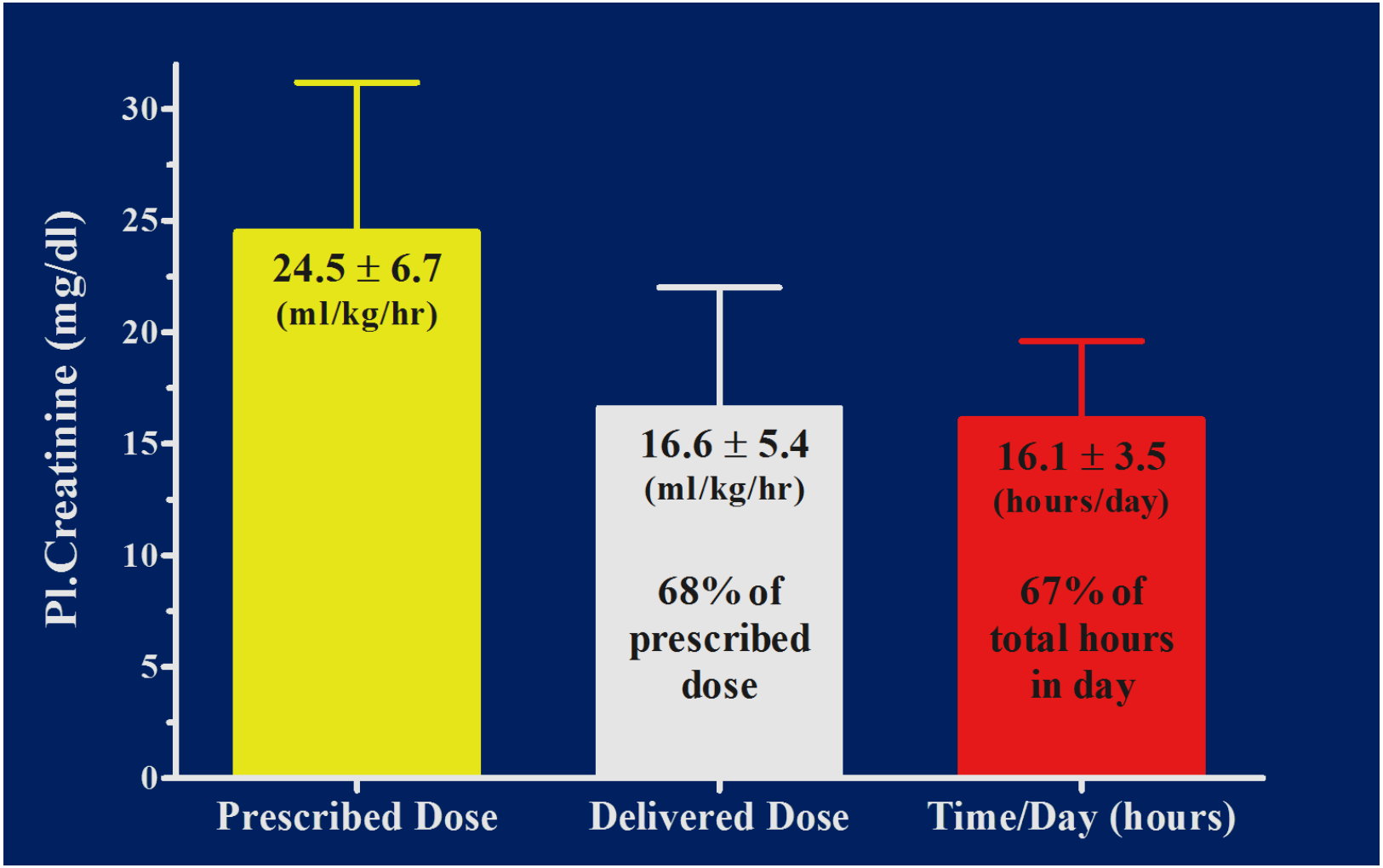
Disclosures

- Consultant for Baxter
- Patent on 0.5% citrate formulation (18/0)

CRRT Prescription vs. Delivery



Venkataraman et al, *J Crit Care, 2002*

Clotting of Filter and Circuit

- Circuit Factors
  - Filtration Fraction
  - De-aeration chamber
- Vascular Access
- Insufficient Anticoagulation

Filtration Fraction (Q_{UF}/Q_P)

High Total UF Rate & low Blood Flow = **CLOTTING**

Case Example:

100 kg M placed on post-dilution CVVH, BFR 150 mL/min, desired CVVH dose 25 mL/kg/hr; hct 30% (desired Total UF Rate = 2500 mL/hr)

FF = 2500/(0.7 X 150 X 60) = 40% !!!

Circuit Considerations

DEAERATION CHAMBER

Access Considerations

- Large diameter / shorter (but appropriate length)
  - Right IJ = 12–15 cm
  - Left IJ = 15–20 cm
  - Femoral = 19–24 cm
- Location
  - Right IJ preferred
  - Subclavian least recommended
- Place tips in appropriate location
  - IJs & SCs → SVC at Caval Atrial Junction
    - Catheter tips ~ 3 cm caudal of the right tracheobronchial angle
    - Approximately 5 cm of carini
  - Femoral → IVC = 24 cm Catheter
- Do not reduce lumen with smaller gauge connectors/3-way stop-cocks

Anticoagulation Options

- Unfractionated heparin
- Regional heparin with protamine
- LMW Heparins
- Citrate
- Thrombin antagonists
- Prostaglandins - PGI_2, PGE_1

CASES

Case 1

A 65 year-old critically ill male with AKI is placed on continuous venovenous hemodiafiltration (CVVHDF) with post filter replacement fluid. He has a hematocrit of 30% and weighs 85 kg. He clots his filter several times in 24 hours.

His CVVHDF parameters are as follows:

Blood flow rate: 150 ml/min

Post-filter replacement fluid rate: 1000 ml/hr

Dialysate: 1000 ml/hr

Fluid removal rate: 100 ml/hr

Anticoagulation: ACD A 2.2% (Citrate) 200 ml/hr

Calcium gluconate infusion: 60 ml/hr

Post-filter iCa 0.51 mmol/L, Systemic iCa 1.1 mmol/L

Case 1

Blood flow rate: 150 ml/min
Post-filter replacement fluid rate: 1000 ml/hr
Dialysate: 1000 ml/hr
Fluid removal rate: 100 ml/hr
Anticoagulation: ACD A 2.2% (Citrate) 200 ml/hr
Calcium gluconate infusion: 60 ml/hr
Post-filter iCa 0.51mmol/L, Systemic iCa 1.1mmol/L

Which **ONE** of the following management options would **BEST** decrease the chance of filter clotting?

A. Switching to heparin anticoagulation
B. Increasing the post-filter replacement fluid rate
C. Increasing the blood flow rate
D. Switching to CVVH
E. Increasing the citrate rate

Case 1 Answer: E

- The accepted targeted standard range in studies for optimal effect of citrate is an iCa level of < 0.4 mmol/L
- Ex-vivo studies demonstrated a dose-dependent inhibition of coagulation with increasing citrate concentrations
- The correlation between concentrations of iCa and clotting times revealed almost no anticoagulant effect when iCa levels were >0.50 mmol/L

Relation between citrate, iCa++ level and ACT

Citrate mmol/L	iCa++ mmol/L	ACT s
0.00	1.18±0.05	101±9
1.13	0.67±0.07	108±13
2.26	0.40±0.07	157±51
3.39	0.28±0.03	327±175
4.52	<0.25	681±267
5.65	<0.25	no clotting

Calatzis A, Toepfer M, Schramm W, Spannagl M, Schiffl H. Citrate anticoagulation for extracorporeal circuits: effects on whole blood coagulation activation and clot formation. Nephron 2001;89: 233-236

Citrate Delivery: Fixed

QB (mL/min)	4% TSC (mL/hr)	ACD-A (mL/hr)
100	175	210
125	218	262
150	262	315
200	350	420

Amount of citrate delivered to achieve blood citrate concentration of 4 mmol/L

QB (mL/min)	4% TSC (mL/hr)	ACD-A (mL/hr)
100	132	159
125	165	200
150	199	239
200	265	319

Amount of citrate delivered to achieve blood citrate concentration of 3 mmol/L

Flanagan MJ et al. AJKD 27: 519-24, 1996

Case 2

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 70 kg. He is on heparin anticoagulation.

Blood flow rate	100 ml/min
Post-filter replacement fluid rate	1200 ml/hr
Fluid removal rate	200 ml/hr

His access is a 13 French 15 cm double lumen catheter inserted in Right IJ. His filter clots 3 times in 24 hrs.

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

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

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

(1200 + 200)/ (6000 X 0.7) = 33%

Filter clotting with FF > 20-25%

Case 3

A 66 year old male developed AKI post-CABG x 3 + MVR. He is 5’11" and weighs 95 kg. His hct is 30%. An 14F - 24 cm double lumen short-term dialysis catheter is placed in his left femoral vein and CVVHDF is initiated using the following prescription: BFR = 100 ml/min, dialysate rate 1200 ml/hr, Post filter replacement fluid 1500 ml/hr.

Arterial access pressure = -25 mmHg

Venous access pressure = 60 mmHg

Case 3

Filter life averaged 16 hours over the net 48 hours. The catheter was easily flushed with saline. You initiate a citrate infusion via a port near the arterial access. Two hours later, the on call physician turns up the blood flow rate to 250 ml/min to decrease filtration fraction and increase sheer. When you arrive in the morning, the filter has clotted again.

Case 3

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

A. Femoral vein location of the catheter.
B. The increased BFR caused catheter failure.
C. The increased BFR prevented the anticoagulant effect of the citrate infusion.
D. Lack of a more effective anticoagulant, such as heparin.
E. Excessive concentrating of the postfilter blood due to the postfilter hemofiltration component of the prescription

Case 4

A 59-year-old man with alcoholic cirrhosis and type 2 diabetes mellitus is admitted to the intensive care unit for severe sepsis from pneumonia. He is given intravenous fluid resuscitation and norepinephrine to improve his mean arterial pressure to 70 mmHg and develops oliguric AKI. His current medications include norepinephrine, cefepime, vancomycin, lactulose, and insulin. On exam, he is intubated and sedated. Laboratory studies show:

Sodium 134 mEq/L
Potassium 5.7 mEq/L
Chloride 102 mEq/L
Total CO_2 20 mEq/L
BUN 84 mg/dl
Creatinine 3.2 mg/dl
Albumin 3.6 mg/dl,
Total calcium 9.1 mg/dl (8.4–10.3 mg/dl)
Ionized calcium 5.0 mg/dl (reference range, 4.48–5.28 mg/dl) (1.25 mM; reference range, 1.12–1.32 mM)

Case 4

CRRT is begun using citrate anticoagulation. Over the next 48 hours, he remains stable, and CRRT is used to achieve a net UF of 100 ml/h.

On the third day of therapy, the following laboratory studies are obtained:
Sodium 137 mEq/L
Potassium 3.8 mEq/L
Chloride 98 mEq/L
Total CO_2 18 mEq/L
BUN 30 mg/dl
Creatinine 2.1 mg/dl
Total calcium 10.4 mg/dl (2.6 mM)
Ionized calcium 3.9 mg/dl (0.975 mM)

Which one of the following is **MOST** consistent with citrate toxicity in this patient?

A. The calcium corrected for the serum albumin
B. The difference in ionized calcium before and after CRRT
C. The ratio of the total calcium to ionized calcium
D. The difference between the total and ionized calcium

Case 5

A 63 year old man develops AKI in the setting of septic shock and necrotizing pancreatitis. He is intubated, requiring FIO2 0.65 and two vasopressors. His HCT is 30%, platelets 35,000, INR 2.2, LFTs: TBili 5.6 mg/dL, AST 3,145 U/L, ALT 2,232 U/L, Lactate 9.3 mmol/L. He weighs 130 kg and is 6 foot 4 inches tall.

Patient is on the following CRRT prescription with the Prismaflex device:
CVVHDF
Blood flow 150 ml/min (decreased from 200 ml/min by the ICU nurse)
Pre-filter RF 1500 ml/hr
Dialysate 1000 ml/hr
Post filter RF 200 ml/hr
Fluid removal 200 ml/hr

He is on no anticoagulation. His access is a 12.5 French 15 cm double lumen catheter inserted in left femoral vein. Arterial pressure = -220 mmHg, venous pressure = 150 mmHg
Deaeration chamber looks as follows:

Case 5

Case 5

He clots his filter 3 times in 24 hours.

Which of the following is the BEST option to minimize further clotting of the filter?

A. Add citrate anticoagulation
B. Increase the fluid level in the deaeration chamber
C. Increase Pre-filter RF to 2200 ml/hr
D. Decrease Post-filter RF to 0 ml/hr
E. Replace the dialysis access

Case 5

A. Add citrate anticoagulation.

B. Increase fluid level in deaeration chamber

C. Increase Pre-filter RF to 2200 ml/hr.

D. Decrease Post-filter RF to 0 ml/hr.

E. Replace the dialysis access.

Patients current prescribed CRRT dose = 2900 ml/hr / 130 kg = 22 ml/kg/hr

Patients current FF = UF/plasma flow rate = 1900 ml / [(150 ml/min X 60 ml)(1-0.3) + 1500 ml] = 24%

A. Patient has shock liver and unlikely to tolerate citrate

B. The fluid level is adequate

C. This increases Filtration Fraction; FF = 2600 ml/[(150 x 60 x 0.7) + 2200 ml] = 31% and will not address access pressures

D. This will cause clotting in the de-aeration chamber of the Prismaflex device

E. Access pressures are high and patient's catheter needs to be at least 24 cm in length for femoral position and tip located in inferior vena cava

Case 6

- 48 YO **80 kg** M with DM II, HTN, osteoarthritis and normal renal function presents with fevers, chills, and rigors to the ED
- Vitals: T 102.6ºF, BP 72/46 mm Hg (MAP 55 mm Hg), HR130 BPM, O_2 Sat 78% on a 100% face mask
- He is intubated and given 4L balanced isotonic fluids without hemodynamic improvement
- He is subsequently started on vasopressors and broad spectrum antibiotics for pneumonia and sepsis
- Home medications: ACE I, metformin, hydrochlorothiazide, and Ibuprofen

Case 6

- 10 hrs. later he remains oliguric, and nephrology consulted
- He remains on vasopressin 0.03 u/min, norepinephrine 10 µg/min; CVP 15 cm H_2O; MAP 65 mm Hg
- Current labs:
  - ABG: pH 7.32/ pCO_2 30/ pO_2 78 on Fi02 1.0
  - Na 135 meq/L, K 5.6 meq/L, Cl 109 meq/L, Bicarb 15 meq/L, BUN 58 mg/dL, Creatinine 5.4 mg/dL (478 µmol/L), Lactate 4.0 mmol/L, Ca 8.4 mg/dl, Alb 3.2, iCa 0.95 mmol/L
  - WBC 37K, hgb 10 g/dl, Plt 80K, Hct 30%,
  - TBili 2.2 mg/dL, AST 100 U/L, ALT 123 U/L, INR 1.5
  - Blood cxs: GNR

Case 6

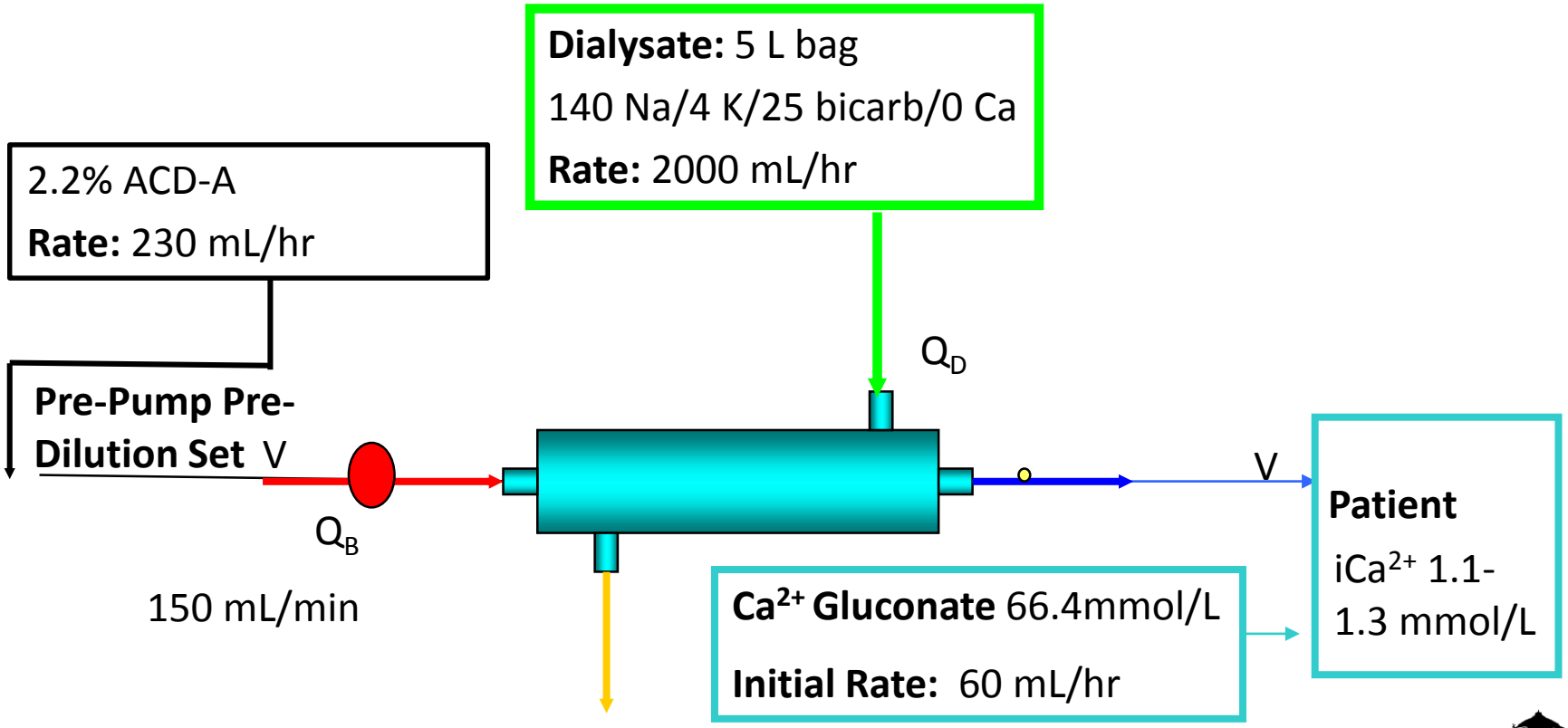
- The patient is placed on CVVHD with following parameters for 48 hrs with correction of electrolytes

- CRRT Parameters (Prismaflex):
  - BF 150 ml/min
  - D 2000 ml/hr (4 K/25 bicarb/ 0 Ca)
  - FR 100 ml/hr
  - ACD-A 230 ml/hr on PBP pump

- CRRT Labs:
  - Post Filter iCa: 0.32 mmol/L
  - Systemic iCa: 1.1 mmol/L
  - Serum Total Ca: 8.2 mg/dl
  - Calcium gtts is at 60 ml/hr

Dose and FF

- Dose = 2330 ml/hr / 80 kg = 29 ml/kg/hr
- FF = (230+100)/[(0.7*9000)+230] = 5%



Low systemic iCa

- Shift change occurs & nurse rushes to change bags
- The new nurse calls you with a systemic iCa 0.67 mmol/L

- What do you do?
  - Ask about patient's overall status and if any changes have occurred
  - Ask from where the Ca level has been drawn
  - Ask what is hanging on PBP scale (is it citrate or something else?)
  - Ask what rate citrate is infusing
  - Ask if calcium is infusing and if so, where is it infusing
  - If appropriate, increase Ca infusion

- 30 minutes later…
  - Pt's BP drops & requires escalation of norepinephrine
  - Telemetry reveals prolonged QTc interval
  - The patient starts seizing and stat labs are sent

Labs

CRRT Parameters (Prismaflex):

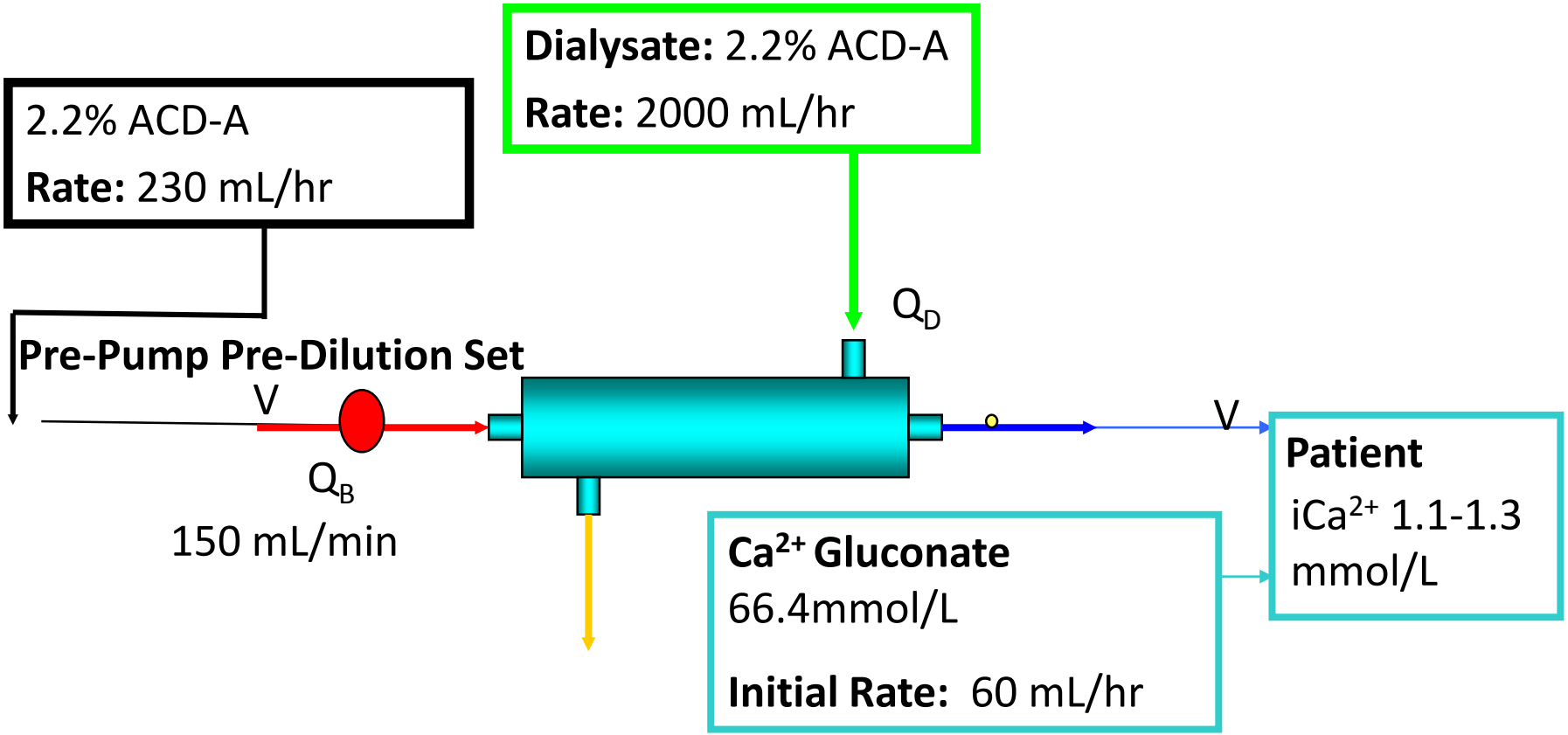
BF: 150 ml/min

D: 2000 ml/hr (4 K/25 bicarb/ 0 Ca)

FR: 100 ml/hr

ACD-A 230 ml/hr on PBP pump

- Stat labs:
  - Systemic total Ca 10.8 mg/dl
  - Systemic iCa 0.70 mmol/L
  - Serum bicarbonate 37 mEq/L
  - Serum Na 154 mEq/L


Dialysate: 2.2% ACD-A
Rate: 2000 mL/hr
2.2% ACD-A
Rate: 230 mL/hr
Q_D
Pre-Pump Pre-Dilution Set
V
V
Q_B
150 mL/min
Patient
iCa^{2+} 1.1-1.3 mmol/L
Ca^{2+} Gluconate
66.4mmol/L
Initial Rate: 60 mL/hr

Determination of Citrate Toxicity

- Patient's citrate toxicity was the result of the nurse hanging citrate (ACD-A) at the stopcock position and in the dialysate position. The patient was receiving 2230 ml of citrate an hour!

- Bonus Question: How would you correct this catastrophe?