CRRT Troubleshooting Guide

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Initial Settings

1. Complete CRRT prescription – use pCRRT orderset – follow pre-printed orders, use post filter replacement (↑efficiency) initially and if tandem in ECLS circuit
2. Blood flow rates –
   - 2-6kg, 5-10mls/kg/min (lower BF allows lower citrate dose and less citrate complications)
   - 6-15kg, 5-8mls/kg/min
   - 15-30kg, 4-6mls/kg/min
   - >30kg, 2-4mls/kg/min
3. Replacement Fluid (RF) Flow rates –
   - maintain filtration fraction < 25% to avoid early filter clotting
   - for equivalent total RF flow rate settings, higher flows of prefilter replacement can be set compared with postfilter replacement before FF >25% is reached
     - adult studies do support pre-filter replacement as extending filter life/limited pediatric information
4. Replacement Fluid (RF) options:
   - citrate anticoagulation – use PrismoCal RF; BCCH chloride solution dialysate
   - heparin anticoagulation / no anti-coagulation - use PrismoSol both RF and dialysate
5. Specific clinical situations:
   - infants under 10kg – previously recommended blood prime circuit. We now propose NOT using blood prime, but to have PRBC at the bedside when indicated, and administering directly to the patient to manage either hypotension on initiation or a low patient Hct
   - metabolic disease (eg. hyperammonaemia/maple syrup urine disease)
     - use CVVHDF/higher than normal **replacement** and **dialysate** flow rates

     (eg. 2x normal – 80-100mls/kg/hr)
   - tumor lysis/hyperkalemia/hyperphospatemia
     - use CVVHDF/higher than normal **replacement** and **dialysate** flow rates

     (eg. 2x normal – 80-100mls/kg/hr)
   - new diagnosis of severe AKI/CKD with significantly high urea (e.g: >40 mmol/L)
     - use lower than normal clearance (20-25mls/kg/hr) to reduce risk of cerebral osmolar shifts - discuss with nephrology
   - fluid overload - fluid removal goals should consider hemodynamic stability, cumulative fluid balance, nutritional needs
6. Dialysis catheter position –internal jugular provides better flows vs femoral in children
   - the relatively small femoral veins of infants compared with an adequate sized dialysis catheters will completely occlude the femoral vein, limiting targeted blood flows
   - elevated abdominal compartment pressures or direct compression by intra-abdominal masses (eg. Burkitt's tumor) can occlude the inferior vena cava and limit femoral venous catheter blood flow

Line Management after Placement

1. Immediately flush and aspirate forcefully to ensure maximal blood flow is possible
2. Immediately flush and 'citrate lock' each lumen with citrate
3. Secure the line – deep cutaneous sutures/sterile transparent dressing
4. When initiating, remove citrate lock, recheck each lumen using saline syringe for maximal positive and negative blood flow just prior to connecting circuit
5. Re-flush lumens with saline – connect access and return lines
6. Initiate blood flow after unclamping all clamps on circuit and line
7. Initiate citrate (mls/hour) at same time as circuit blood flow (mls/minute) /close monitoring of hemodynamics during first initiation imperative. (see hypotension on initiation)
8. Increase blood flow to max set flow over next 2-3 minutes/monitor hemodynamics

9. Consider ultrasound of neck vessels if persistent problem with cannula lumen obstruction – looking for clot

Hypotension on Initiation of CRRT

1. Anticipate and be prepared:
    a. check patient blood volume status/check Hb-Hct - consider packed cells available at bedside for initiation
    b. normalize serum iCa^{++} prior to initiating CRRT (patient iCa^{++} > 1.0, preferably closer to 1.2) – recommend infusion at 1-2 mmol/kg/day during setup, depending on baseline patient iCa^{++} level may require a $CaCl_2$ bolus – check level immediately prior to connecting to circuit
    c. medications:
        - $CaCl_2$ 10mg/kg centrally
        - Na_2HCO_3 1-2mmol/kg IV push
        - 5% albumin 30ml syringes x 2
        - Consider PRBC depending on initial Hct (30ml syringe x 2)
        - epinephrine 10mcg/ml dilution syringe (dose 1mcg/kg)
2. Potential leaching of agent from filter – recommended time to connect < 30minutes of saline flush

Initial Circuit Pressures

- Initial circuit pressures will vary and be dependent:
    - on blood flow rates
    - cannulae function/lumen size and patency/tip location
    - whether the patient is on ECLS

Be aware of initial filter pressures (TMP and ΔP) and **track trends** to identify potential problems early.

- ***Non*-ECLS**

Filter pressure is usually reflective of what's happening with the return pressure in the initial start-up phase

- Low negative access pressure - less than -100 on recommended full blood flow, regardless of filter size and catheter size
- Low return pressures - less than + 100 on full recommended blood flow
- Low filter pressures – low + 100

- ***ECLS***
    - Access and return pressures will be **positive** and reflect ECLS circuit pressures which is dependent on ECLS flow - will become more positive as the circuit clots, access clots.

Catheter Failure

1. Disconnect and recirculate to CRRT circuit – options include:
    a. flush catheter – aspirate – identify lumen with least resistance and reconnect access to this port
    b. decreasing blood flow rate will lower access negative pressure and may prolong circuit function (but reduce efficiency of clearance) and increase risk of circuit clot
    c. rewire catheter for new vascath

Rising/High Filter Pressures

Filter Relevant Definitions:

- *TMP = [filter pressure + return pressure]/2 – effluent pressure*
- *Filter pressure drop = filter pressure – return pressure*
- *FF is calculated using BFR, RF rates and hematocrit (ensure the correct daily hematocrit has been entered into the Prismaflex)*

ALWAYS start by troubleshooting the catheter access and return lumens

1. High negative access pressures – catheter problem (kinked/clotted)
    a. check that cannula is not kinked/twisted under dressing/entry under skin/ adhering to vessel wall, check CXR if catheter insertion site captured on image

b. patient sedation/ coughing, position (i.e. where the line is placed puts it at increased risk of occlusion)

2. High filter pressures
    a. increased blood flow (pressures will go up and down with changes in circuit blood flow)
    b. increased replacement fluid flow rate
    c. increased fluid removal flow rate
    d. clogging/clotting filter, as indicated by:
        - high TMP
        - increased pressure drop across filter
        - normal return pressures
    e. obstructed return lumen (kink/clot), as indicated by:
        - normal TMP
        - high return pressures
3. Increasing TMP
    a. excessive effluent dose (too much sucking)
        - either reduce ultrafiltration rate, or
        - increase blood flow (being mindful that this will require an increase in citrate flow and increase citrate patient load) if cannulae and filter can tolerate/can maintain clearance by increasing dialysate flows without causing an increase in TMP
    b. increased protein adsorption to filter membrane surface causing clogging and reduced surface area
    c. clotting/clogging filter or de-aeration chamber
4. Increasing effluent pressure
    a. circuit clotting/clogging
    b. increased/altered effluent dose
5. High filtration fraction – maintain < 25% - options
    a. adding dialysate or increasing dialysate flow rate has no influence on filter pressure or FF
    b. switch replacement to pre-filter
    c. reducing replacement fluid flow rates
    d. increasing blood flow rate
6. Basic…site to source of lines from patient to machine

Short Filter Survival

1. Check catheter for kinks/check catheter for ability to tolerate high access flows using test syringe withdrawal
2. Check filtration fraction – aim for < 25%
3. Confirm circuit iCa^{++} levels in recommended range (0.9-1.2mmol/L)
4. Increase blood flow rate/reduce effluent dose to reduce filtration fraction (FF)/consider adding dialysate or increase dialysate dose to optimize clearance while minimizing an increase in FF
5. Does the accessed vessel have a large clot – consider US of vessel or angiogram
6. Consider changing/adding heparin anticoagulation

Fluid Balance Issues

1. Net negative fluid balance should start cautiously, but can be aggressively increased, depending on the clinical situation, with careful ongoing clinical hemodynamic monitoring
2. ALWAYS rely on clinical examination to confirm calculated fluid balance – ***if the child is clinically dry, they are dry*** – track daily weights, daily "ins and outs" look for edema, sunken eyeballs, increasing HR (consider insensible losses)

Acid Base Abnormalities

Use the circuit to manage arterial metabolic acid base problems– for example, if a metabolic alkalosis has developed, do not reduce ventilation with permissive hypercarbia – correct the primary metabolic problem.

In critically ill unstable children, initial pH often includes a metabolic lactic acidosis. CRRT may be initiated initially in these situations with both dialysate and replacement fluids Prismocal (for citrate) or PrismoSol (for heparin) to enhance clearance of the lactate and associated acid (proton).

Once the patient has stabilized, different metabolic pH abnormalities can develop depending on the type of anticoagulation (citrate vs heparin) and initial CRRT prescription dialysate and RF flow rates. Examples of the conditions that might develop during citrate anticoagulation include:

a. normal arterial pH 7.4
   - replacement fluid Prismocal/dialysate fluid BCCH chloride solution (equal flow rates – and titrate up or down as pH changes, at prescribed flow rates according to order set)
   - if alkalemic (serum bicarbonate > 30mmol/L), titrate BCCH Chloride solution flow rate > Prismocal flow rate
   - if acidemic (serum bicarbonate < 22mmol/L), titrate Prismocal flow rate > BCCH Chloride solution flow rate

b. check patient blood gas pH/bicarbonate as per protocol

Acidemia

1. Avoid:
   - bicarb infusions-boluses
   - adding non-standard medications to CRRT solutions
2. Exclude an oxygen delivery issue – check patient serum lactate. Enhance oxygen delivery.
3. Citrate toxicity can cause a metabolic acidosis (but usually associated with alkalaemia).
4. Adjust replacement and dialysis solutions
   - replacement fluid – Prismocal with citrate regional anticoagulation
   - dialysate – BCCH Chloride solution or Prismocal, depending on the blood pH

a) Mild Acidemia pH 7.25 – 7.35
   - if BCCH Chloride solution as dialysate, consider reducing flow rates to zero
   - no improvement/worsening acidaemia – may need to add Prismocal to dialysate and increase replacement and dialysate fluid flow rates – beware unwanted increased clearance of medications/other electrolytes
   - consider a new onset condition contributing to acidosis (e.g. sepsis, ischemic bowel, extensive necrotic tissue)

5. Severe Acidemia pH < 7.25
   - replacement fluid and dialysate fluids both Prismocal at recommended rates (or higher as prescribed by physician)
   - check pH every 1-2 hours
   - may need to increase both dialysate and RF flow rates for short period of time until acidaemia starts to correct. Monitor blood pH/bicarbonate and titrate flows as per protocol.

Alkalaemia

Alkalaemia will almost always occur with citrate anticoagulation over initial 24-48 hours of CRRT, depending on the blood flow rate and citrate flow rates – anticipate. Consequence of the metabolism of citrate (1mole citrate metabolized to 3moles of bicarbonate).

1. Use the circuit to manage metabolic alkalaemia
2. Rule out citrate toxicity (calcium gap > 2.5, and sometimes a high anion gap) - check serum total and ionized Ca levels to confirm/ eliminate possible cause of alkalaemia
3. Adjust replacement and dialysis solutions
   a. always have Prismocal as replacement fluid
   b. dialysate – Chloride solution or Prismocal, depending on the clinical situation and initial blood pH
4. Alkalaemia pH > 7.45
   a. If Prismocal RF:dialysate flows 1:1, increase BCCH Chloride solution to achieve ratio of Prismocal BCCH solution 1:2
   b. check patient pH every 1-2 hours initially
   c. titrate flows up or down depending on pH response
   d. consider reducing BF and citrate flow rates to reduce the citrate load (see citrate toxicity)

Citrate Toxicity

1. Cardinal features
    a. metabolic alkalosis (most often) *OR high anion gap* metabolic acidosis
    b. Calcium lock syndrome (most common clinical expression): low patient ionised calcium with a high (or normal) total calcium
2. Predisposing factors
    a. severe liver disease (unable to metabolise the citrate)
    b. decreased hepatic blood flow (e.g. in sepsis or other shock states)
    c. neonates/small infants
    d. patients also receiving PLEX
    e. rising systemic calcium infusion flow rates > 2.5mmol/kg/day/patient alkalaemia
    f. Use of high blood flow rates/high citrate flow rates for circuit integrity, especially in small infants
3. Prevention
    a. anticipate – avoid excessive blood flows (and corresponding high citrate requirements)
    b. daily total calcium levels as per guidelines, monitor total Ca/iCa < 2.5
    c. avoid circuit iCa^{++} < 0.25 in patients under 10kg
4. Management
    a. reduce blood flow rate to allow a reduction in citrate infusion (but could increase the risk of clotting circuit)
    b. reduce citrate infusion rates independent of BF in order to reduce citrate exposure and allow for intrinsic citrate clearance
    c. turn off citrate infusion (30 minutes, and recheck level) in order to reduce citrate exposure and allow for intrinsic citrate clearance – monitor circuit and patient iCa^{++}
    d. increase citrate clearance – increase both RF and dialysate flow rates to clear citrate/calcium complexes
    e. increasing dialysate flows can increase clearance without an effect on circuit pressures or FF
    f. reduce calcium infusion rates
    g. monitor patient and circuit iCa^{++} and patient serum total every 1-2 hours until corrected, or circuit clots
    h. if the above actions do not correct the citrate toxicity, consider alternative anticoagulants if no contraindications e.g. heparin, no coagulation in patients with a coagulopathy

Other Questions:

1. Why is the jugular vein the preferred access site for CRRT?
    - femoral vein in infants is too small for the large dialysis catheter – catheter obstructs lumen of vessel and limits flow
    - intra-abdominal hypertension is a contraindication to using the femoral vein (inadequate blood flows)
    - mobilising patient more difficult with femoral lines (even in older kids) because more likely to kink with positioning
2. Can the subclavian vein be used?
    - yes, in larger kids, but subclavian stenosis a longer-term risk
    - catheter is at risk of kinking under the clavicle in children under 20kg and in obese patients
3. Can calcium infusion be infused into return access site?
    - yes, but risks clotting of return access lumen and Health Canada opposing additional connections in circuit due to risk of critical incident
    - in an emergency or if there is no other central access, calcium can be connected to the return lumen in the short term
4. What about thrombocytopenia?
    - avoid giving platelets unless clinical bleeding as thrombocytopenia may prolong filter life. On the flip side, giving platelets may increase the risks of filter clotting
5. Why can't we add extra potassium to the dialysate and replacement bags?
    - ideally, we do not change the standard concentrations in the solutions prepared by Pharmacy. These concentrations have been identified as the optimal concentration for patient safety and minimizing anticipated complications of our therapy.
    - Preferably, if supplementation is required, such as for hypokalemia, it is ideal to give through the gut. Other forms of nutrition, such as TPN, or a 0.5mmol/kg bolus intravenously may be considered based upon the clinical case.
    - In extreme circumstances, the concentration maybe changed but will require a specific prescription. It is better to manage electrolytes via adjusting replacement fluid and dialysate flow rates over continual bag changes.
6. What if the line keeps clotting?
    - see line placement
    - if no contraindications, give heparin (50units/kg) immediately after line placement and after flushing lumens with saline/citrate until prescribed circuit flows have been established
7. What about drugs and nutrients?
    - consult PICU pharmacist/physician for issues pertaining to unanticipated consequences of CRRT on drug clearances (majority of drug clearance is via convection), and nutritional losses (greater risk with higher effluent doses)
8. What about children presenting with hypernatremia?
    - consult pharmacy, nephrology for issues and special prescriptions that might be required
9. What about patients with liver dysfunction/failure?
    - patients in liver failure still require anticoagulation (regional) as they have a higher rate of developing clots than bleeding (procoagulant vs anticoagulant balance is disordered)
10. What about patients with AKI and septic shock?
    - patients in septic shock still require anticoagulation (regional) as they often have a procoagulant vs anticoagulant imbalance, unless they have severe thrombocytopenia
11. My patient has platelet count < 50,000. Should I give him platelets?
    - platelet transfusions during CRRT will clot the filter. If the patient is not bleeding, thrombocytopenia will prolong filter life and need not be correct unless the patient is scheduled for a procedure or is bleeding
12. Can I override the circuit expiry warning so the circuit will run longer than the 72 hours?
    - no, this is a recommendation from the manufacturer. Due to a critical incident in another Canadian centre in which the blood pump circuit ruptured, Baxter no longer support the practice of 'overriding' the alarm. Legally, Baxter will take no responsibility for any critical events that occur after this time.

- additionally, after this period of time consideration should be paid to circuit functionality. In particular, protein coating of the filter and clot formation reducing efficacy of circuit function.