Continuous Kidney Replacement Therapy (CKRT) in the Children's Intensive Care Unit (ICU)

For the purposes of this document and accompanying computerized physician/nurse orders, the use of "CKRT" is interchangeable with the term Continuous Renal Replacement Therapy (CRRT).

Contents

Introduction

CKRT is the filtration of blood through a hollow fiber, semi permeable membrane outside of the body (extracorporeal circuit). CKRT is a slow, continuous (24 hours/day) therapy. The different modes of CKRT used are: slow continuous ultrafiltration (SCUF), continuous venovenous haemodialysis (CVVHD), continuous venovenous haemofiltration (CVVH) and continuous venovenous haemodiafiltration (CVVHDF).

Principles of CKRT

- Convection (CVVH or CVVHDF)
    - One-way movement of solutes through a semi-permeable membrane with water flow. Also known as solvent drag. The faster the effluent flow rate, the higher the clearance.
    - This modality has better middle-molecule clearance which may allow removal of inflammatory molecules (e.g. sepsis, SIRS).
    - Aim to keep filtration fraction at <20-25% to prolong filter life
        - Filtration fraction is calculated and indicated by Prismaflex machine
        - To decrease filtration fraction
            - Increase blood flow rate
            - Decrease replacement flow rate and increase dialysate flow rate
            - Avoid large increases in set hourly UF rates
            - Convert to CVVHD
- Diffusion (CVVHD)
    - Movement of solutes through a semi-permeable membrane from area of higher concentration to that of a lower concentration until equilibrated
    - This modality may allow higher ultrafiltration rate and result in longer filter life if middle-molecule clearance is not required

Definitions

SCUF	• Fluid is removed by ultrafiltration • There is minimal solute removal by this method
CVVH	• Blood is removed from the patient via one lumen of the dual-lumen catheter and pumped through the extracorporeal circuit and haemofilter • Solute is removed via convection • This is the default mode of choice in our unit when initiating CKRT • Fluid replacement is required- we practice pre-filter fluid replacement in our unit
CVVHD	• Blood is removed from the patient via one lumen of the dual-lumen catheter and pumped through the tubing circuit and haemofilter • Solute is removed by diffusion from the blood (higher concentration) to the dialysis solution (lower concentration) that runs countercurrent to the blood flow.
CVVHDF	• Solute removal is by both diffusion and convection • Both dialysis solution and replacement solution are required

Single-pass albumin dialysis	• Promotes removal of protein-bound substances
	• Indicated in rare cases of specific conditions
	  ○ Wilson's disease: remove copper
	  ○ Protein-bound drug intoxications (e.g. carbamazepine, midazolam, fentanyl)
	• 20% albumin added to the dialysis solution (to achieve ~5% albumin dialysis solution)
	  ○ E.g. Exchange 1250ml of 20% albumin for 1250ml of dialysate in a 5-L bag (i.e., 250g of albumin in 5000ml)

Indications for CKRT

- Diuretic unresponsive volume overload
- Hyperkalaemia
- Intractable acidosis
- Progressive oliguria/ kidney failure
- Inborn errors of metabolism e.g. hyperammonemia
- Intoxication of dialyzable substance

How to administer CKRT

Roles of medical team

- Each patient is assessed, on an individual basis, to the need for starting kidney replacement therapy by the intensive care physician in discussion with the nephrologist.
- Doctor in charge in ICU prescribes the CKRT order.
- Staff Nurse in ICU will prepare, prime, initiate and terminate the CKRT treatment.
- Pharmacist in ICU will review medications daily and advise on dose adjustments

General Steps

- Informed consent
    - Informed consent must be obtained for insertion of the vascular access as well as initiation of CKRT before the implementation of CKRT
    - In situations where CKRT is considered to be urgent and life-saving, verbal consent may be obtained first before the informed consent form is signed
    - An information leaflet will be given to patient/parents/guardian. (See "Continuous Kidney Replacement Therapy Information Leaflet")
- CKRT Order Sheet
    - The intensive care physician orders the blood flow rate, dialysate flow rate, replacement flow rate, fluid removal rate, potassium additives (if Prismasol used) and anticoagulation on a CKRT order sheet in the SCM system for paediatric patient (See "Continuous Kidney Replacement Therapy Prisma Order Sheet") / CKRT form for adult patients (See Annex 5).
    - Initiation of continuous kidney replacement therapy via central venous catheter
- Doctor to be present before initiating treatment
    - Possible complications during initiation:
        - Risk of haemodilution/hypotension especially in small infants where circuit volume is greater than 10-15% of patient blood volume
            - Consider topping up PCT prior to, during or soon after initiation of CKRT
            - Stand-by resuscitation fluids and drugs
            - May need to increase ongoing inotropic infusions during initiation
        - Bradykinin release syndrome- associated with AN69 membrane
            - Thought to be related to bradykinin release when patient's blood contacts with the haemofilter, more commonly seen when blood priming the circuit.
            - Related to pH (acidosis) -> attempt to correct metabolic acidosis prior to initiation if using AN69 membrane haemofilters
            - Manifestations: bronchospasm, hypotension, mucosal congestion at start of CKRT
            - Stand-by resuscitation fluids and drugs

Vascular access

- Vascular access is achieved by the insertion of dialysis catheters into the femoral, internal jugular or subclavian veins. Size and number of lumens of the catheter will depend on weight of patient as well as catheter availability.
- Vascular access to be obtained by aseptic technique

Table of recommended Cannula sizes based on weight (NFK KNOQI2006)

Weight of patient (Kg)	**Cannula size**
Neonate	Single lumen 5F
	Double lumen 6.5F
3-6	Double lumen 6.5F, 7F
6-15	Double lumen 8F, 9F
15-30	Double lumen 10F
>30	Double lumen 11.5F
	Triple lumen 13F

In the event that recommended catheter sizes are not available, suggest measuring vascular diameters via US to guide selection of the next best catheter size available. Catheter size (French) = diameter (mm)/3

Equipment

- PRISMAFLEX machines
    - This machine allows the following modes of CKRT: SCUF, CVVH, CVVHD and CVVHDF
- Haemofilter
    - The haemofilter is a semi permeable membrane that allows the passage of water and dissolved solutes

Characteristics	**M60**	**M100**	**HF20**
Patient weight (Kg)	11-30	>30	*</=10
Membrane	AN69	AN69	PAES
Surface area (m^2)	0.6	0.9	0.2
Blood volume in set ± 10% (ml)	93	152	58
Minimum blood flow rate (Qb ml/min)	50	75	20

**Off-label use of HF20 for <8kg infants.*

Blood flow rate (Qb)

Qb is generally set at 4-5 ml/kg/min for paediatric patients, and up to 10-12ml/kg/min for neonates/infants. Qb for adults is generally set at 100-250 ml/min

- However, adjustment to Qb may be needed with the following considerations:
    - Filter
        - Higher Qb reduces filter clotting, resulting in longer filter life
        - Increase blood flow rate if there is rising haemofilter transmembrane pressures, increased filtration fraction or clot formations
    - Access
        - Reduce blood flow to address rising access pressures.
        - Increase blood flow to reduce clot formation in catheter.
    - Citrate delivery
        - Decreasing blood flow results in lower citrate infusion requirements
    - Fluid and solute removal
        - Increase blood flow rate to provide greater filter plasma flow rates and reduces the loss of clearance efficiency but this applies more for intermittent haemodialysis (IHD) than CKRT.

Dialysis and replacement solutions

- Prismasol BO and Biphozyl are isotonic solutions used for both replacement and dialysis solutions
- Prismasol BO is used in heparin-free dialysis with systemic heparin coagulation and is potassium-free
- Biphozyl is used in dialysis with regional citrate anticoagulation as it does not contain calcium
- Composition of Prismasol BO and Biphozyl:

	Biphozyl	**Prismasol BO**
Sodium (mmol/l)	140	140
Potassium (mmol/l)	**4**	**0**
Chloride (mmol/l)	122	109.5
Calcium (mmol/l)	**0**	**1.75**
Magnesium (mmol/l)	0.75	0.5
Lactate (mmol/l)	0	3
Osmolality (mOsml/l)	290	287
Glucose (mmol/l)	0	0
Bicarbonate (mmol/l)	22	32
Phosphate (mmol/l)	1	0

- In the event that Prismasol BO is used, to order potassium additives to be added to the Prismasol dialysis solution:
    - K </= 5 mmol/L: Add 4mmol/L of K+ (in ratio of 2mmol/L KCl and 2 mmol/L KH2PO4) -> this can be adjusted according to patient's requirements
    - K > 5 mmol/L: no added K+ to the dialysis solution
- Total dialysate and/or replacement flow rates is 2 L/1.73 m^2/hr
    - For CVVHDF mode, the combined replacement and dialysate flow rate is set at 2 L/1.73m^2/hr unless otherwise indicated by ICU consultant.
    - E.g. For a patient with body surface area (BSA) 0.7 m^2:
      Dialysate and/or replacement flow rate (ml/hr) = 2000 ml x 0.7 m^2 / 1.73m^2 = 809 ml/hr
      Therefore:
        - CVVHD: dialysate flow rate ~800 ml/hr
        - CVVH: replacement rate ~800 ml/hr
        - CVVHDF: combined rate of dialysis fluid and replacement fluid should total ~800 ml/hr
            - E.g., 400 ml/hr of dialysis fluid + 400 ml/hr of replacement fluid
            - The proportion of dialysate and replacement fluid rates may be adjusted based on clinical situations (i.e., whether more diffusion or convection required, whether ultrafiltration rate is high)

Ultrafiltration rate (UF rate / Qnet)

- This is dependent on the patient's haemodynamics.
    - Increasing vasopressor support may be required for patients to tolerate fluid removal.
- Ultrafiltration rate per hour: 0.5-2 ml/kg/hr
    - The maximum UF rate is 13ml/kg/hr for intermittent haemodialysis (IHD) but it is unknown for CKRT
- Daily negative balance: as clinically indicated
    - Generally: 0–5% of body weight
    - The maximum daily fluid removal rate is unknown and suggested to be about 10% of body weight

Anticoagulation

- Anticoagulation is usually needed to prevent clotting of the extracorporeal circuit
- In patients with disseminated intravascular coagulation and high activated clotting time, dialysis without anticoagulation may be considered in patients with high blood flow rate and a large dialysis catheter
- Regional citrate anticoagulation
    - Performed by introducing citrate into the blood as it leaves the patient and enters the circuit
    - Citrate binds calcium, lowering the ionized Ca2+ in the blood. This prevents the blood in the circuit from clotting
    - A calcium infusion is given to the patient to normalize the serum ionized Ca^{2+}
    - This results in an anticoagulation of the circuit without anticoagulation of the patient (see "Citrate Protocol for Continuous Kidney Replacement Therapy")
- Systemic heparin anticoagulation
    - Heparin is given as a form of systemic anticoagulation
    - Patient is at risk of bleeding
    - A heparin bolus followed by an infusion is given to achieve a target activated clotting time (ACT) of 180-220 seconds (see "Heparin Protocol for Continuous Kidney Replacement Therapy")

Patient monitoring

- All patients on CKRT will have continuous cardiac rhythm and arterial blood pressure monitoring
- For paediatric patients, the renal panel (serum urea, creatinine and electrolytes) and blood gases are monitored 4 hourly initially. Serum calcium, magnesium and phosphate are monitored twice daily on the first day of CKRT and may be reduced to daily thereafter.
- For adult patients, the blood tests are to be done according to Intensivist's orders

Protein nutrition in children on CKRT

- Protein intake >1.5 g/kg/day was associated with the greatest reduction in mortality for critically ill children
- Recommended protein intake in children with AKI without dialysis is 2 g/kg/day
- Due to excessive amino acid losses in CKRT, current nutritional recommendations for adults and children receiving CKRT is a daily intake of amino acids of 3–4 g/kg/day
- Under most circumstances, a serum urea 14-21 mmol/L and a normal serum albumin are reliable indicators of adequate amino acid/protein intake, especially in patients on CVVHD or CVVHDF with high clearance rates

Sodium adjustments

- If higher serum sodium levels are indicated (e.g., neuroprotection),
    - Adjust sodium content in IV fluids or TPN
    - Adjust sodium concentration in dialysate
- To avoid rapid changes in serum sodium, increase or decrease sodium concentration in dialysate solutions by 5 mmol/L above or below serum sodium levels
    - For example, if the patient's serum sodium is currently 135 mmol/L and the aim is to maintain serum sodium at 150 mmol/L,
        - The target serum sodium concentration in CKRT (first column of the table below) should be 140 mmol/L first.
        - Once patient's serum sodium reaches 140mmol/L, we can then further increase the target serum sodium concentration in CKRT to 145 mmol/L.
        - Similarly, once patient's serum sodium reaches 145 mmol/L, we can then further increase the target serum sodium concentration in CKRT to 150 mmol/L.
- Aim to increase serum sodium by <10mmol/L over 24 hours

Target serum sodium concentration in CKRT solution (mmol/L)	NaCl 20% to be added (per litre)	NaCl 20% to be added per 5L bag
145	1.47 ml/L (5 mmol/L)	7.4 ml
150	2.94 ml/L (10 mmol/L)	14.7 ml
155	4.41 ml/L (15 mmol/L)	22.1 ml
160	5.88 ml/L (20 mmol/L)	29.4 ml

Priming of Continuous Kidney Replacement Therapy circuits using Prismaflex machine

- Perform medical hand washing.
- Counter-check doctor's order in SCM CKRT ordersheet.
- Prepare the followings:
  Prepare heparinsed saline in a 50 ml syringe, dosage as per doctor's order (For Heparin protocol) To be infused via systemic route.
  Add 10,000 unit of heparin into the 1 litre normal saline bag (10 units of heparin per ml of normal saline) for priming
- Prime set when ready to start treatment.
- Perform medical hand washing.
- Open PrismaFlex set.
- On the PrismaFlex machine:
  - Select new or same patient.
  - When choosing therapy, select CVVHDF mode – as this mode allow access to other modes therapies.
  - Load the PrismaFlex set onto the machine and follow the step-by-step instructions on the screen.
  - Prepare dialysate/ replacement solutions and connect lines to solutions as instructed on the screen.
  - Select "Prime" after the connection of the lines to the solutions is complete
  - First prime with heparinised normal saline (10 units per ml) as prepared earlier to coat the surface of the tubing and filter with heparin.
  - Re-prime the PrismaFlex circuit with 1 litre of normal saline.
  - Inspect the set for air and observe closely for leakage at joints and connections within the system during priming.
  - Once the priming process is completed and the "self-test" is passed, the machine is ready for use.
  - If the circuit is not used on patient for more than an hour, re-prime the circuit manually with 300 ml of normal saline.
  - Do not use the PrismaFlex set if the circuit is left unused for more than 8 hours.
  - Important Note: Press "CONTINUE" key ONLY when patient is ready to start CKRT.

Initiation of Continuous Kidney Replacement Therapy via Vascular Catheter

- Doctor to be present before initiating treatment.
- Before the procedure, the nurse should:
  - Counter-check and key-in CKRT order on the PrismaFlex machine with another RN.
  - Assess and record patient's haemodynamic status
  - Assess catheter site for redness and swelling
- Put on mask and apron.
- Perform surgical hand washing.
- Prepare the following in a sterile dressing set:
  - Don on sterile gloves
  - Pour normal saline 0.9% into the compartment
  - Pour in cleansing solution chlorhexidine 2% / alcohol 70% (Paeds) /
    Prepare Chlorhexidine 2% with isopropyl alcohol 70% swabs (Adults)
  - Add in the syringes and gauze
- Drape catheter site with sterile towel.
- Scrub the arterial and venous lumen of the catheter access ports one at a time with chlorhexidine 2% / alcohol 70% for one minute.
- Remove catheter caps and discard.
- Connect a 3ml syringe filled with 1ml 0.9%NaCl to arterial port (red).
- Aspirate 1.5 ml (Paeds)/ 10ml (Adult) of blood and spread the blood onto a piece of gauze to check for blood clots.
- Flush with 3ml (Paeds)/ 10 ml (Adult) of 0.9%NaCl into the catheter and clamp with positive pressure.
- Repeat steps for the venous port (blue).
- Connect arterial and venous lines and ensure that there is no air bubble within the line.
- Release all clamps on access lines.
- Initiate CKRT treatments as per Doctor's order.

- Secure lines with micro-pore tape.

For Troubleshooting Prismaflex alarms, refer to the CKRT Troubleshooting Protocol

Termination of Continuous Kidney Replacement Therapy from Prismaflex machine

- Ensure that termination of CKRT is ordered in the patient's case-notes.
- Put on mask and apron.
- Prepare the followings in a sterile dressing set:
  - Pour cleansing solution into compartment
  - Open and put in all stopcocks, syringes, needles, and transparent dressing
- Perform surgical handwashing before putting on sterile glove.
- Prepare heparinised saline to heparin lock lumens of dialysis catheter.
  - < 5kg –660 units in 20ml normal saline (33u/ml)
  - > 5kg – 2000units in 20ml normal saline (100u/ml)
  - Adult 1000u/ml without dilution
- Prepare 2 x 3ml syringes with the prepared heparinsed saline/ heparin.
- Filled the 2 x 5ml (Paeds)/ 2 x 10mls (Adults) syringes with 0.9% NaCl
- Termination is operated through the interactive display screen.
- Standby mode is automatically entered when pressing the stop button on the Status screen.
- Select "END TREATMENT" from the screen.
- To return blood to the patient, select "RETURN BLOOD" from the next screen. Follow the instruction on the "RETURN BLOOD" screen.
- Select "DISCONNECT" if end treatment without returning blood. Follow instruction on the "DISCONNECT PATIENT" screen
- Hang the bag of 0.9% NaCl at lower left corner of PrismaFlex machine.
- Clamp the access port (red) of patient's catheter.
- Clean connecting section with chlorhexidine gauze (Paeds) / Chlorhexidine 2% with isopropyl alcohol 70% swabs (Adult) as per manufacturer guide for one minute
- Disconnect access line from patient.
- Attach 3ml (Paeds)/10ml (Adult) syringe to access port.
- Unclamp the access port.
- Aspirate 2 – 3 ml (Paeds)/10ml (Adult) of blood from the lumen.
- Squelch aspirate on gauge to check for any blood clot.
- Flush access port with 0.9% NaCl.
- Check patient's catheter to determine the amount of heparin to be injected. The volume should not exceed the amount indicated on the lumen.
- Heparin lock lumen and clamp port.
- Cap lumen with stopcock.
- Connect access line (from PrismaFlex machine) to the bag of saline using spike
- Hold down "START RETURN" key on the screen to return desired amount of blood. WARNING: Do not return blood if clotting is present in blood lines or filter.
- Repeat steps with the venous port (blue).
- Change dressing at exit site if soiled or wet.
- Secure the catheter down with micropore tape to keep it from dangling and to prevent dislodgement.
- Press "CONTINUE" key on screen.
- Press "UNLOAD" to unload pump segments from pump raceways from the next screen
- Clamp all lines attach to bags.
- Disconnect lines from all bags.
- Remove and discard the set, solution bags and effluent bag.
- Press "TREATMENT HISTORY" to view treatment history data from the last 24 hours.
- Record post dialysis parameter.
- Turn off machine and power point.
- Wipe the machine with medic wipe before storage.

General Guidelines for the Prismaflex machine

- The Vendor will do the scales calibration six monthly.
- Set up therapy in CVVHDF mode ONLY to allow user to change the mode during therapy if desired. This allows access to the other modes of therapy at any time.
- When priming - add 10,000 IU heparin/L of 0.9% NaCl to the priming solution.
- Do not inject medications into the circuit, it is a low compliance system and will not accept fluids pushed into the ports
- Never use the STOP button to trouble shoot alarms. This will cause the circuit to clot off prematurely
- Use the HELP menu to assist in troubleshooting
- Do not hang any bag on the other scale when the machine is not in used.
- In the event of a cardiac arrest. Turn the PrismaFlex machine off and disconnect the circuit from the patient.
- The machine indicates that the circuit needs to be changed at 72 hours. The yellow caution light remains on when 72 hours passes. Change circuit after 120 hours if circuit remains patent.

- For patients who are in disseminated intravascular coagulation–consult medical team whether to use heparinised prime. If not re-prime with normal saline. The circuit needs an initial prime with Heparin to coat the surface of the tubing and the filters. To empty the prime collection bag before re-priming
- Caution: To release all clamps on fluid lines before initiation to avoid system from withdrawing fluid off the patient. The machine will stop the blood pump when it detect an incorrect weight change. There is a “Incorrect Weight Change” management feature on the Prismaflex which will limit how much extra fluid can be removed from the patient in excess of the prescribed set rate. Once this limit is reached, the machine will alert user to end treatment and shut the machine down.

- To start Anticoagulant Citrate Dextrose Solution (ACDA and IV $CaCl_2$ 15-20mins after initiation of CKRT.
- During initiation, to start Blood Flow Rate (BFR) at slower rate and gradually increase as tolerated.
- When using Prismasol BO solution, to add KCL /KH_2PO_4 in dialysate solution for CVVHD mode, to replacement solution in CVVH mode and both dialysate and replacement solutions in CVVHDF mode, as per CKRT ordersheet.

ANTICOAGULATION FOR CONTINUOUS KIDNEY REPLACEMENT THERAPY

REGIONAL CITRATE ANTICOAGULATION

Principles of Citrate Anticoagulation

Citrate ($C_6H_5O_7$) is an organic acid. It is used as an anticoagulant in our protocol as acid citrate dextrose (ACD) solution (3.22% citrate, 112.9 mmol/L citrate, 123.6 mmol/L glucose, 224.4 mmol/L sodium and 114.2 mmol/L hydrogen ions). Citrate binds calcium in the blood with the formation of citrate–calcium complexes (CCC), thereby reducing the level of ionized free calcium (Ca^{2+}). Ca^{2+} is a mandatory co-factor of most enzymes of the coagulation cascade. The reduction of Ca^{2+} results in anticoagulation of the blood. Post-filter Ca++ is monitored to ensure adequate anticoagulation and to permit citrate dose adjustment. Calcium replacement is required for the patient to prevent hypocalcaemia and this is done with an infusion calcium chloride solution through a separate central line. Regular monitoring of systemic, post filter and total calcium is required to maintain adequate anticoagulation, ensure normocalcaemia and monitor for citrate accumulation (total Ca_{tot} / Ca^{2+}).

Citrate Clearance and Metabolism

CCC has a low molecular weight and its clearance via the CKRT is high, with a sieving coefficient 1.0. This clearance can be increased by increasing the dialysate flow rate in the diffusive method or the filtration flow rate (in PrismaFlex it is the "replacement flow rate") in the convective method. CCC which are not cleared is returned to the patient and metabolized via the Krebs (citric acid) cycle in liver, muscle and kidney, generating HCO_3^- and releasing Na^+ and Ca^{2+} in the process.

Citrate and Acid-Base Balance

Citrate is a weak acid. In the blood, it mainly exists as CCC with 2 of its 3 carboxylates bound with calcium, further weakening its plasma acidification effect. If citrate catabolism is normal, the regional citrate anticoagulation leads to plasma alkalinization due to HCO_3^- generation.

Citrate Accumulation ("citrate lock")

The body's capacity to metabolize citrate is saturable. When this capacity is exceeded, citrate accumulates as CCC. This is reflected as an increase in Ca_{tot} / Ca^{2+} ratio (>2.5). This happens especially in shock states and liver failure when the ability to metabolize citrate is reduced. This can result in life-threatening hypocalcaemia. An increase in the calcium infusion needed (binding of calcium to citrate) and lactic acidosis (reflects underlying pathology that impairs tricarboxylic cycle) may be warning signs.

Net citrate overload

Net citrate overload occurs when there is excessive citrate administration or low clearance of citrate in the haemofilter. The body's capacity to metabolize citrate is not reached and the CCC is all metabolized. The Ca_{tot} /Ca^{2+} is not raised and serum Ca^{2+} remains normal. Metabolic alkalosis is commonly observed. Troubleshooting includes ensuring that the circuit setup is correct (e.g. citrate infusion is not given post filter), citrate delivery is not continued when the pump is stopped, the clearance (dialysis or haemofiltration rates) is adequate and filter function is intact (e.g. filter clotting).

Management of citrate accumulation/ overload

For both citrate accumulation and citrate overload, the strategy is to reduce the net citrate load by:

- Reducing the citrate infusion rate
- Increasing clearance (increase dialysis or haemofiltration rate)
- Decreasing target concentration in Ca^{2+} in the circuit (risk of clotting)

In citrate overload, this problem is usually fixed with reduction with citrate delivery. In citrate accumulation, if no improvement is observed quickly with the interventions, an alternative anticoagulation should be considered as the risk of hypocalcaemia can be life-threatening.

Excess calcium load

There may be circumstances when the set calcium infusion may be excessive due to the addition of other sources of calcium (e.g., milk feeds), resulting in a scenario high total Ca but a desired Ca_{tot} / Ca^{2+} ratio. This then results in an upward titration of ACD-A infusion to maintain post filter Ca^{2+} level in the circuit, which then can result in a drop in patient's systemic Ca^{2+} level. This further increases the calcium infusion rate if the protocol is followed. In such a circumstance, consideration is required to re-set the titration regime for citrate infusion and calcium infusion, taking into account the trend of post filter Ca^{2+}, patient's systemic Ca^{2+} and patient's $Ca_{tot.}$ Inform nephrologist or CICU consultant if there is suspicion of excess calcium load.

Workflow for citrate anti-coagulation

1. Prime in CVVHDF Mode using ordered dialysate and replacement solutions.
   Dialysate: HCO_3-based without Ca (Biphozyl)
   Replacement: normal saline or HCO_3-based (Biphozyl)

2. When ready to start, the citrate rate in ml/hr will be 1.5 x the blood flow rate (BFR) of the Prismaflex machine at ml/min. (e.g. start Citrate at 150 ml/hr if the BFR is 100ml/min)

3. Set up the Ca^{2+} infusion (i.e. 8 g Calcium Chloride in 1L 0.9% NaCl or 23.5 g of Calcium Gluconate in 1L of NS) as ordered via central line other than the dialysis access (unless using the 3rd lumen of a triple lumen vascath) . This will run at 40% of the citrate flow rate. (e.g. citrate rate = 150 ml/hr then CaCl rate = 60 ml/hr)

4. Set the flow rates in Prismaflex machine as ordered.

5. Patient Fluid Removal Rate is calculated by:
   Net Ultrafiltration rate + Citrate rate + Calcium infusion rate = Pt. Fluid Removal Rate.

6. Connect the Prismaflex machine circuit to the dialysis catheter as per procedure and press start.

7. 2 hours after initiation of therapy and every 6 hours thereafter, send the following blood tests:
   - Post-filter ionized Ca^{2+} (drawn from the return line, blue sample port)
   - Systemic ionized Ca^{2+} (drawn from patient (true) arterial line or peripheral draw)
   - Renal Panel, Calcium / Magnesium / Phosphate (see # 14 for citrate and calcium adjustment)

8. Metabolic alkalosis occurs due to citrate metabolism to bicarbonate and due to bicarbonate in the Dialysate. Call ICU consultant if the Serum Bicarbonate is >
   35 mmol/l. ICU consult may add in NS as a replacement solution by 20% and decrease the dialysate rate by the same amount if patient is on CVVHD, or add NS as a dialysate solution by 20% and decrease the replacement rate by the same amount if the patient is on CVVH. This will give an acid load from the 0.9% NaCl and reduce the HCO3 from the bath at the same time.

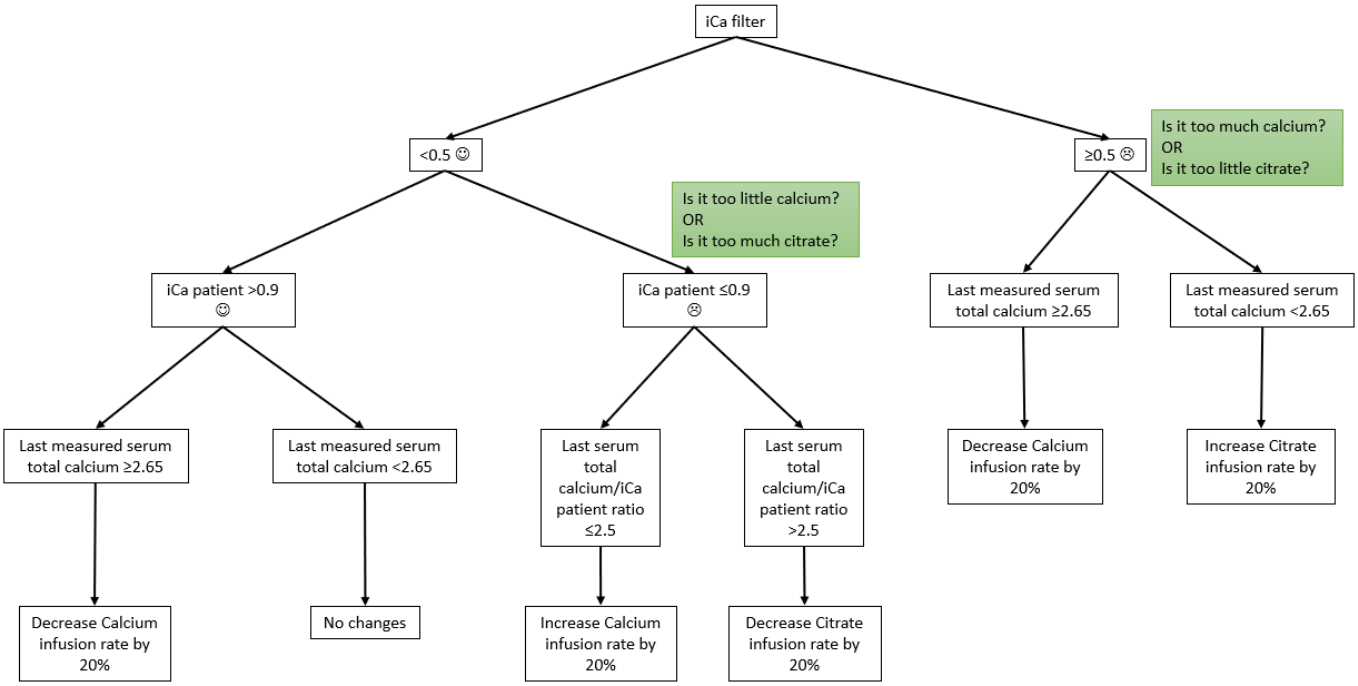
9. Notify ICU consultant for the following:
   a. Systemic Ionized Ca^{2+} < 0.75 mmol/L. (Consider holding citrate for 1 hour and resuming infusion at 30% of the citrate flow rate and bolus with 10 mg/kg of CaCl and increase Ca infusion by 10%)
   b. Na^+ > 150 mmol/L. Consider changing replacement solution to 0.45% NaCl.

10. If the filter clots, stop the Citrate and Ca^{2+} infusions and discontinue the filter.

11. **In children less than 10 kg who require a blood transfusion while initiating CKRT, avoid the use of citrate for the first 15 minutes as it may exacerbate the bradykinin release syndrome seen in some children.**

12. Citrate Lock occurs when the total calcium rises with a dropping ionized calcium.
    This is because the citrate infusion exceeds the clearance on dialysis and from hepatic metabolism. When this is seen, stop the citrate for 1-2 hours then restart at 70% of the previous dose. Stop the CaCl infusion at the same time and resume at 40% of the citrate flow rate when it is restarted. Watch the ionized calcium during this time to avoid inadequate anticoagulation of the circuit (i.e. the ionized calcium of the system rising causing system clotting). Inform ICU consultant is citrate lock is persistent.

13. Titrate the Citrate infusion according to the flowchart citrate sliding scale below:



- All units are in mmol/L
- Patients with liver dysfunction are rarely put on citrate anticoagulation
- If liver dysfunction develops and there is suspicion of citrate gap, please inform Renal on call before performing citrate lock

Note:
Monitor for "Citrate Lock" using the following formula:

Ratio of Ca_{tot} / Ca^{2+} > 2.5

Ca_{tot} – Total calcium (NOT ADJUSTED total calcium)
Ca^{2+} – Ionised calcium

Inform ICU consultant / Nephrologist on call if total calcium is abnormally high (i.e. above lab reference range) but ratio of Ca_{tot} / Ca^{2+} < 2.5.

Heparin Protocol for Continuous Venovenous Haemodialysis and/or Haemofiltration

1. **Before Initiation**
   - Obtain baseline Full Blood Count, PT/PTT, Fibrinogen and Activated Clotting Time (ACT).
   - Correct haemoglobin, platelets, PT and fibrinogen if deranged, as indicated, in discussion with the with ICU consultant.
   - If patient's ACT < 140s, consider giving a bolus of heparin at 20 units/kg to patient and recheck ACT.
   - Repeat heparin bolus and ACT check until ACT 180-220s. (maximum 2 boluses of heparin).

2. **During Haemodialysis or Haemofiltration**

   - When ACT > 160s, start heparin infusion (10 units/ml) at 10 units/kg/hr. Check system ACT 30 minutes after initiation.
   - Titrate heparin infusion to keep post-filter ACT between 180-220s.

   - If the ACT is <180s:
     - if ACT is 160-180s: increase heparin infusion by 10%
     - if ACT is 140-160s: increase heparin infusion by 20%
     - if ACT < 140s: consider heparin bolus 10-25units/kg and increase heparin infusion by 20%. Inform ICU consultant.

   - If the ACT is >220s:
     - if ACT is 220-240s: decrease heparin infusion by 10%
     - if ACT is 240-260s: decrease heparin infusion by 20%
     - if ACT >260s: Inform ICU consultant.

3. **ACT monitoring**
   - With each circuit change and when platelets or blood are administered to the patient**,** obtain postfilter (blue port) ACT every 30 minutes until ACT is stable between 180-220s.
   - Monitor ACTs 30 min after any heparin change.
   - Monitor ACTs every four hours once stable

Patient Sticky Label

CONTINUOUS KIDNEY REPLACEMENT THERAPY PRISMA ORDER SHEET

Weight (kg)		**Height (cm)** _____	**BSA (m^2)**	_____
Allergy		**Date** _____		
Catheter	_____	_____Fr	_____cm	Site _____
Filter	HF20	M60	M100	
Mode	SCUF	CVVH	CVVHD	CVVHDF

Blood flow (ml/min) Paediatrics (4-5 ml/kg/min) Neonates/infants 10-12 ml/kg/min) Adults 100-250 ml/min	Start at	_____	Target	_____
Replacement rate (ml/hr) (2 L/1.73m^2/hr)	Start at	_____	Target	_____ _____
Dialysate rate (ml/hr) (2 L/1.73m^2/hr)	Start at	_____	Target	_____
With citrate anticoagulation Citrate infusion rate (ml/hr) 1.5 x blood flow rate $CaCl_2$ rate (ml/hr) 40% of Citrate rate	Start at Start at	_____ _____	Titrate citrate and $CaCl_2$ infusion rates as per citrate protocol	
With heparin anticoagulation Heparin infusion dilution (Systemic) Heparin loading Heparin maintenance infusion ACT Monitoring (baseline, 1hr and 4-6hrly)	Dilute _____U heparin in 50ml N/S (Amt= Wt(kg)x10Ux50) 1ml/hr = 10U/kg/hr Bolus 20U/kg; 2ml of 50ml syringe Continuous infusion at _____ml/hr Baseline ACT _____ (normal 80-120) Keep ACT between _____ and _____ Increase or decrease by 10%			
Fluid removal rate (ml/hr) _____ (A+C-B) A: Intake (IV fluids, drug volume, fluid replacement, TPN, blood products, calcium infusion, citrate infusion) B: Output (urine losses, drains losses) C: Desired negative balance (maximum negative balance or UF rate = 12ml/kg/hr)				
Inform the MO if MAP drops below _____mmHg				

Solutions used	**Replacement Fluid**	**Dialysate Fluid**
Biphozyl (used in citrate anticoagulation only)		
PrismaSol BO		

If **PrismaSol BO** is used as a replacement or dialysate solution, add 2mmmol/l of KCl and 2mmol/l of KH_2PO_4 to the solution unless serum K is >5mmol/l or the patient has a risk of rapid rise in serum K or phosphate, such as in severe burns, massive trauma or severe tumor lysis.

Biphozyl contains physiological concentrations of potassium and phosphate.

Priming solution (Avoid blood prime with M60 or M100)	First prime: 1000ml Heparin Saline (10,000U/L)	2nd prime: 1000 ml normal saline
Connecting to patient	Heparinized prime can be given to patient within 1hr prime* If machine is stagnant >1hr after priming, perform manual prime with 300ml N/S and load heparin 20U/kg	
Recirculation	Use N/S for re-circulation. Dilute 100U heparin per 100 N/S Maximum re-circulation time is 2hrs Heparin locked lumen; <5kg (33U heparin/ml) >5kg (100U heparin/ml)	

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CONTINUOUS KIDNEY REPLACEMENT THERAPY (CKRT) INFORMATION LEAFLET

This leaflet serves to provide patient/parents with some general information on continuous dialysis/filtration for children who are critically ill at our Intensive Care Unit.

Patient/Parents are encouraged to discuss any concerns or doubts regarding their child's condition with the doctor-in-charge.

What is CKRT?

CKRT is a 24-hour continuous haemodialysis. Haemodialysis is a process by which blood is drawn from a patient and passed through an external circuit where toxins and/or fluid are removed. This is usually done for patients with kidney failure, fluid overload or intoxication with a substance that can be removed by dialysis.

How does CKRT work?

This involves the insertion of a dialysis catheter into a big vein – the femoral vein in the groin or the subclavian/ internal jugular veins in the neck.

In the intensive care unit where the patients are critically ill, dialysis is done by a continuous process where blood is drawn from one lumen of the catheter, "cleansed" in the dialysis circuit and returned to the patient in the second lumen of the catheter, throughout the day.

What are some of the risks associated with CKRT?

1. To prevent blood in the dialysis circuit from clotting, medications are given to the patients. This is usually done by giving a medication (anticoagulant) to bind calcium (which is needed for normal clotting) when the blood is in the dialysis circuit. Calcium is then replaced via a separate catheter into the patient. Sometimes, heparin is used instead. Heparin also prevents blood from clotting in the patient and can cause patient to bleed more easily. The choice of the anticoagulant is based on the medical condition of the patient. Blood tests are done on a regular basis to ensure adequate anticoagulation and safety of the dialysis.

2. Whenever a tube is inserted into a blood vessel there is an increased risk of infection. Signs of infection are watched for carefully and antibiotics given if needed.

3. During initiation, instability of the blood pressure is sometimes encountered. This will be monitored closely and necessary action will be taken as required.

4. As the catheter is relatively large, it can sometimes impair the blood flow in the limb (if inserted in the leg) or clots can form in the vein. Change of the catheter or the site of insertion of the catheter may be required.

How long will patient be on CKRT?

The duration of use of CKRT is dependent on return of kidney function for the case of kidney failure. For the case of toxin removal, it is stopped once the toxin in the body is reduced to a safe level.

Care for patients under CKRT

During the course of CKRT treatment, the patient will be reviewed daily and his condition monitored closely by the team. Blood tests to monitor the kidney and electrolyte status will be done regularly.

The Family's Role

Parents and family members, including siblings play an important role in the child's care and recovery. Find out more about family-centred care and early mobilisation via the posters within our ICU. Visitation is strongly encouraged.