APPENDIX B-1
CLINICAL PRACTICE GUIDELINE

TITLE:	Continuous Renal Replacement Therapy (CRRT) Management Guideline	ORIGINAL DATE: September 2021
IDENTIFICATION NUMBER:	CG 21006	LAST REVISION DATE: September 2021
HOSPITAL(S) Hamad General Hospital ,*ALL HMC HOSPITALS / ENTITIES*		NEXT REVIEW DATE: September 2024
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1.0 PURPOSE (AIM):

To define the principles, indications, contraindications, complications and various modes of Continuous Renal Replacement Therapy (CRRT). To provide the nephrologists a guideline to write CRRT orders, understand and troubleshoot common CRRT machine alarm. Also, to provide CRRT nurses (dialysis nurses and trained ICU nurses) and hemodialysis technologist a guideline for initial machine setup, maintenance of CRRT, understand and troubleshoot common CRRT machine alarms.

2.0 DEFINITIONS:

CRRT is an extracorporeal blood purification over an extended period and applied for 24 hours a day. In CRRT, blood is pumped out of the venous system of the patient, passed over an artificial semi-permeable membrane (hemofilter) where fluid and solutes are removed by (ultrafiltration/convection) or (diffusion) and then the cleaned blood is returned to the patient via the same double lumen venous dialysis catheter.

3.0 APPLIES TO: Nephrologist, intensivist, nurses, dialysis technicians and pharmacist.

4.0 PATIENT GROUP: Adult patients

5.0 EXCEPTIONS: Children

6.0 TARGET AREAS: All inpatient areas with intensive level of care

7.0 GUIDELINES:

7.1 Principles of Renal Replacement Therapy

7.1.1 Ultrafiltration: is the movement of fluid across a semi-permeable membrane driven by a hydrostatic pressure gradient. In CRRT a positive pressure is generated by the blood pump in the blood side of the semi-permeable membrane and a negative pressure generated on the other side (maintained by the effluent pump)

resulting in the movement of fluid from the blood (positive pressure side) to the negative pressure side.

7.1.2 Convection: solutes removed as a result of "solvent drag" during ultrafiltration via pressure gradients. It occurs when large volumes of fluid cross the semi-permeable membrane down the hydrostatic pressure gradient (as in ultrafiltration). These large fluid volumes are generated by the addition of replacement solution (replacement fluid) to the blood side of the filter (either pre- or post-filter and described as pre-dilution or post-dilution). It is important for middle and large molecules clearance.

7.1.3 Diffusion: removal of solutes across the semi-permeable membrane driven by their movement down a concentration gradient. It is created by the addition of dialysate solution on the opposite side of the filter to the blood. (i.e. dialysate flow is counter current to the blood flow). It is effective for removal of smaller molecules with greater concentration gradients.

7.1.4 Filters used in CRRT machines have larger pore size than classical intermittent hemodialysis filters, allowing passage of molecules up to 50,000 Daltons across the filter. Small molecules (e.g. urea, creatinine, ammonia) are more efficiently removed by diffusion but larger molecules (myoglobin, inulin and interleukins) are better removed by convection.

7.2 Modes of Continuous Renal Replacement Therapy

CRRT modes comprise four therapies depending on the mechanism involved:

7.2.1 Continuous veno-venous hemofiltration (CVVH): Effective modality of solute removal and fluid management, especially middle and larger size molecules (up to 50,000 Daltons), by convection. It requires the addition of replacement fluid to drive convection (either pre-filter or post-filter). No dialysate fluid is used. The amount of fluid in the effluent bag is equal to the amount of fluid removed from the patient (ultrafiltration fluid) plus the volume of replacement fluid given.

7.2.2 Continuous veno-venous hemodialysis (CVVHD): Basically, it is intermittent hemodialysis performed continuously. It is effective for removal of small and middle molecules and fluid management by diffusion. It requires the addition of

dialysate fluid, in a counter current direction, on the opposite side of the filter to the blood to drive diffusion. No replacement fluid is used. The amount of fluid in the effluent bag is equal to the amount of fluid removed from the patient (ultrafiltration fluid) plus the volume of dialysate fluid given.

7.2.3 Continuous veno-venous hemodiafiltration (CVVHDF): is a combination of CVVH and CVVHD. In this mode there is clearance by both convection and diffusion. It is effective for removal of small, middle and large molecules and safe management of fluid overload. It requires the addition of replacement fluid to the blood side of the filter (either pre-filter or post-filter) to drive convection and dialysate fluid placed counter current to the blood flow on the opposite side of the filter to create concentration gradients for diffusion. The amount of fluid in the effluent bag is equal to the amount of fluid removed from the patient (ultrafiltration fluid) plus the volume of dialysate and replacement fluid given.

7.2.4 Slow continuous ultrafiltration (SCUF): removal of fluid at low rate via hydrostatic pressure gradient. It does not require replacement or dialysate solution. It is effective for fluid overload without need for solute clearance. The amount of fluid in the effluent bag is equal to the amount of fluid removed only (ultrafiltration fluid).

7.3 Timing of initiation of renal replacement therapy:

7.3.1 The optimal timing of initiation of renal replacement therapy (RRT) for patients with AKI has been debated for decades. However, there is a strong consensus on starting RRT when one of the following conventional indications doses exist:

7.2.1.1 Refractory hyperkalemia (> 6.0 mmol/L).
7.2.1.2 Refractory metabolic acidosis (pH <7.2 and HCO3 <15 mmol/L).
7.2.1.3 Refractory volume overload (pulmonary edema)
7.2.1.4 Signs of uremia, such as pericarditis or encephalopathy.

7.3.2 Most randomized control studies do not support routine early initiation of dialysis in the absence of one of the conventional indications and should be initiated in carefully selected cases with specific indications.

7.4 Modalities of renal replacement therapy in AKI:

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7.4.1 Hybrid modalities: Slow low efficiency dialysis (SLED): it is the modalities of choice in our institution.
7.4.2 Continuous renal replacement therapy (CRRT): indicated in certain situation.
7.4.3 Intermittent regular hemodialysis (IHD): limited for stable patient.
7.4.4 Peritoneal dialysis: Not used for AKI in our institution

7.5 Indications to choose CRRT:

Although available evidence shows no clear superiority of one modality of RRT, in general, over another, consider CRRT in the following cases:

7.5.1 AKI with hemodynamic instability and on two or more vasopressors
7.5.2 AKI in patients with acute brain injury, raised intracranial pressure, generalized brain edema, hepatic encephalopathy or post brain surgery
7.5.3 Acute kidney injury post cardiac surgery

7.6 Contraindications to initiation or continuation of CRRT:

7.6.1 Appropriateness for conventional hemodialysis or Sustained Low Efficiency Dialysis.
7.6.2 Patient and/or family refusal for renal replacement therapy.
7.6.3 Lack of vascular access for CRRT.
7.6.4 Terminal disease with no reasonable expectation for recovery.
7.6.5 Irreversible terminal liver failure in a patient who is not a candidate for liver transplantation.

7.7 Dialysis Dose in CRRT:

7.7.1 Standard dose:
- 25 ml/kg/hr.
- It is the recommended dose for most cases.

7.7.2 High dose:
- 40 ml/kg/hr.
- Routine use is not supported by current evidence but can be used briefly for 24 hours at the discretion of nephrologist in hyper-catabolic patient who needs high level of solute clearance not met by standard dose.
- Should be avoided in the first 24 hours of CRRT.

7.7.3 Low dose:
- 15 ml/kg/hr.

- May be considered in patient whom metabolic derangement resolved and still cannot tolerate SLED.

7.7.4 The dose of CRRT is the effluent flow rate (= ultrafiltration rate + dialysate fluid flow rate and/or replacement fluid flow rate). However, the ultrafiltration rate varies every few hours depending on patient hemodynamic and the goal of fluid balance and can be zero. Therefore, in clinical practice prescribed dialysis dose counting only the dialysate fluid flow rate and/or replacement fluid flow rate.

7.7.5 Typically, in CVVHDF mode, the total dose is divided up into dialysate fluid (70%) and replacement fluid (30%).

7.8 Choosing the CRRT mode:

7.8.1 No current evidence exists to support choice of specific CRRT mode. Therefore, the choice remains dependent on unit/clinician preference.

7.8.2 General principle in choosing CRRT mode:

Indication for CRRT	Modality
Volume overload only	SCUF
Solute clearance ± volume overload	CVVH, CVVHD, or CVVHDF
Hypercatabolic ± volume overload	CVVHDF

7.8.3 The default setting for the Prismaflex CRRT machine should be CVVHDF mode, as it permits easily changing from one mode to another without the need to reset the machine or change the circuit; e.g. you can change to CVVH by turning the dialysis flow rate to zero or to SCUF by turning both dialysis flow and fluid replacement rate to zero.

7.9 CRRT fluid choice:

7.9.1 The default starting fluid in CRRT is bicarbonate buffered solution with 4 mmol/L potassium (Prismasol 4 or similar).

7.9.2 Other fluid can be used according to patient's need.

7.9.3 There are many commercial replacement fluids in regular use at HMC which contain physiological levels of sodium, calcium, magnesium, phosphate, glucose and bicarbonate buffer. Whereas potassium level in the fluids varies (0, or 2, or 4 mmol/l) and its use depend on the patient serum potassium level.

7.9.4 To avoid human errors in generating custom fluids at IV room, the safest approach is to use commercially available dialysate and replacement fluids. Limiting the addition of other electrolytes to the CRRT fluids, except potassium chloride, is of paramount importance resulting in less prescription mistakes in the additive dose and fluid contamination with endotoxin and bacteria.

7.9.5 If needed potassium chloride can be added to dialysate/fluid replacement bag to obtain the desired potassium bath e.g. adding 20 mmol potassium chloride to 5 liters CRRT fluid bag of 0 mmol/L potassium to make a final concentration of 4 mmol/L potassium.

7.9.6 Likewise, the addition of bicarbonate to CRRT fluids is discouraged due to increasing sodium concentration and risk of contamination. If there is difficulty improving pH using a commercially available CRRT fluid (bicarbonate level is 35 mmol/L), the option is either increase clearance rate >35ml/kg/hour or use of a separate supplemental IV bicarbonate infusion 150 mmol in 850 ml dextrose 5%.

7.10 Vascular access for CRRT:

7.10.1 An uncuffed non-tunneled dialysis catheter is preferred, unless a cuffed and tunneled catheter is already present.

7.10.2 Arteriovenous fistulas (AVF) or grafts (AVG) are not suitable for CRRT, given risk of needle dislodgment and bleeding as well as continuous needle trauma to the access.

7.10.3 In a patient receiving Extracorporeal Membrane Oxygenation (ECMO), CRRT can be connected to ECMO circuit without the need for access, (see 7.18).

7.10.4 These sites will be used in order of preference for insertion of dialysis catheter:

7.10.3.1 Right jugular vein
7.10.3.2 Femoral veins.
7.10.3.3 Left Jugular vein.
7.10.3.4 Subclavian vein, non-dominant; should be the last resort.

7.10.5 Catheters will be placed using ultrasound-guidance.

7.11 Initial set-up and maintenance of CRRT:

7.11.1 A formal nephrology consultation must be obtained prior to initiating CRRT, to do full assessment regarding the cause and management of AKI and the need and modality of RRT.

7.11.2 A signed consent form or emergency consent (as per HMC policy No CL 7226) must be obtained prior to initiating RRT.

7.11.3 All CRRT orders (initiation, modification and discontinuation) should be entered by nephrologist.

7.11.4 Nephrologist should write a detailed CRRT prescription order in Cerner indicating the specific mode of CRRT (CVVH, CVVHD, CVVHDF or SCUF), type of hemofilter (M150 or any special filter like OXIRIS), blood flow rate (ml/min), replacement fluid and/or dialysate fluid flow rate (ml/hour), ultrafiltration rate (ml/hour), specific potassium bath (which include 0 or 2 or4 mmol/L) and whether or not anticoagulation is needed (Appendix 1).

7.11.5 A range of hourly fluid ultrafiltration will be specified in the nephrologist's order after discussion with the ICU team and based on the goal of net fluid balance and anticipated fluid intake and output over the coming 24 hours. Hour to hour fine adjustment of the fluid ultrafiltration rate within the specified range will be done by CRRT nurse and according to intensivist instruction.

7.11.6 The targeted net fluid balance will be assessed by intensivist regularly (e.g. every 8-12 hours) and instruct CRRT nurse to adjust the hourly fluid ultrafiltration within the prespecified range. The intensivist will discuss with the nephrologist to adjust the prespecified range of hourly fluid ultrafiltration in the order set if necessary.

7.11.7 The initial set-up of the CRRT system will be performed by the hemodialysis technician or CRRT nurse (dialysis nurse and trained ICU nurse) with the backup

of hemodialysis technician and according to nephrologist' order. Subsequent management of the CRRT circuit, patient monitoring and disconnection from therapy will be done by the CRRT nurse with the backup of hemodialysis technician.

7.11.8 Nurse: patient ratio of 1:1 is required during CRRT.

7.11.9 Anticoagulation will be performed as per nephrologist order (with No anticoagulation as a default order in our institution), however, systemic heparin anticoagulation may be used if the patient has increased CRRT circuit clotting tendency without bleeding risk. If the patient is not already on anticoagulation by ICU team (e.g. ECMO patient), order will be entered by nephrologist and typical order is: unfractionated heparin 2000-2500 units IV bolus followed by a continuous infusion of 5–10 IU/kg/hour into the inflow part of the dialysis circuit, before the filter. APTT is maintained between 1.5–2.0 times normal and follow hospital heparin protocol. [Addendum One: Procedure for Priming Circuit (Prepare anticoagulant)].

7.11.10 Nephrologist should calculate filtration fraction (FF) and document it in his/her Cerner note at the initiation and any modification of CRRT orders. (Appendix 2)

7.11.11 The patient will be weighed daily during CRRT therapy.

7.11.12 Vital signs will be monitored and recorded hourly by the nurse.

7.11.13 CRRT nurse will adjust the ultrafiltration rate (UF) in CRRT machine every 1-4 hours to achieve the targeted net fluid balance (Appendix 3 and 4).

7.11.14 During the CRRT session, the CRRT nurse should record and enter in the Cerner CRRT dialysis flowsheet, the mode of CRRT, type of hemofilter, the blood flow rate, replacement and dialysate fluid flow rate, hourly fluid removal (UF) rate set in CRRT machine, hourly actual fluid removal rate (hourly machine output), hourly net fluid balance (that include all the output, including fluid ultrafiltration by CRRT machine, subtracted from all fluid intake) and 24-hour net ultrafiltration.

7.11.15 CRRT nurse will do lab work up and check the results according to the orders.

7.11.16 CRRT nurse will notify the nephrologist/intensivist if there are abnormal laboratory results and he/she will manage electrolyte abnormality according to the sliding scale (Appendix 5).

7.11.17 CRRT nurse will notify the nephrologist and intensivist if there are signs of clotting in the CRRT circuit or infection at the hemodialysis catheter exit site.

7.11.18 It is recommended not to use a single CRRT circuit more than 72 hours and should be changed.

7.11.19 See addendum 1,2,3, and 4 for detailed technical steps for priming, connecting and disconnecting CRRT.

7.12 Entering the typical CRRT order in Cerner.

7.12.1 (Refer to Appendix 1)

7.13 Management of acid-base disturbances and electrolytes depletion during CRRT.

7.13.1 (Refer to Appendix 5)

7.14 CRRT in patient with serum sodium abnormality:

7.14.1 In patient with severe hyponatremia, either a peripheral or post-filter infusion of dextrose 5% could be used to decrease the overall sodium concentration and avoid rapid correction of serum sodium and osmotic demyelination syndrome (Appendix 6).

7.14.2 In patient with severe hypernatremia and cerebral edema, either a separate or post-filter infusion of 3% hypertonic saline could be used to maintain serum sodium concentration in the range of 150-155 mmol/L to avoid worsening of brain edema (Appendix 6).

7.15 Complications of CRRT:

7.15.1 They are similar to conventional hemodialysis but at low incidence and include volume deficit (due to excessive UF without enough fluid replacement),

hypotension, hypothermia, bleeding and vascular access complications. Acid-base and electrolyte imbalance (if not managed correctly) including hyponatremia, hypernatremia hypokalemia, hypophosphatemia and hypocalcemia.

7.16 CRRT in patient receiving Extracorporeal Membrane Oxygenation (ECMO):

7.16.1 During ECMO, CRRT can be provided by introducing a CRRT circuit into the ECMO circuit (integrated system) or independently via a separate catheter and circuit (parallel system).

7.16.2 Parallel system: When using a parallel system, CRRT and ECMO are provided independently via separate catheters and circuits. It has the advantage of providing CRRT independent of ECMO and therefore it is the preferred, if feasible, approach. However, there is a need to insert separate vascular access with additional risk of bleeding and infection.

7.16.3 Integrated system: The integrated approach includes the connection of CRRT circuit into the ECMO circuit. The CRRT circuit can be combined with the ECMO circuit in various ways, however the blood should always be returned to the ECMO circuit before the oxygenator to reduce the risk of air entering the circuit and thrombosis. The obvious benefits of this approach are that no additional vascular access or anticoagulation is necessary. However, the differences in pressures can pose potential difficulties and require changing the pressure range in CRRT set up.

7.17 CRRT circuit hemodynamic:

7.17.1 CRRT machine record two type of pressures:

- Measured Pressures: Access pressure, filter pressure, effluent pressure and return pressure.
- Software-Calculated Pressures: Transmembrane pressure and filter pressure drop

7.17.2 Access Pressure (Arterial lumen, inflow pressure):

- Pressure created by pulling blood from patient and is measured between the catheter and the blood pump.
- It is an indirect indicator of the quality and function of the vascular access and patient hemodynamic.
- Usually negative: -30 to -150 mmHg. Alarms if < -250 mmHg.
- Usually positive if connected to ECMO circuit post pump: +10 to +100 mmHg.

7.17.3 Filter Pressure (Prefilter pressure):

- Pressure to push blood through filter and is measured between the blood pump and the filter.
- Always positive, 100-250 mmHg, and higher than return pressure.
- It indicates the hemofilter functional state (resistance) and the flow distal to the blood pump.

7.17.4 Effluent Pressure

- It is measured in the effluent compartment, between the filter and the effluent pump.
- Can be either positive or negative, depending on whether fluid is being pushed or pulled from the blood compartment to the fluid compartment
- It is affected by ultrafiltration rate and membrane pore permeability.

7.17.5 Return Pressure (Venous lumen, Outflow pressure)

- It is pressure created by returning blood to patient and is measured between the filter and the patient on the return line.
- Always positive and normal 50-150 mmHg. Maximum 300.
- It indicates the resistance/pressure needed to overcome in order to return blood to patient.

7.17.6 Transmembrane Pressure (TMP)

- It reflects the pressure difference between the blood and fluid compartments of the filter and indicate the status membrane pore permeability

- (TMP) = (Filter pressure + Return pressure) / 2 – (Effluent pressure)
- TMP above +300 mmHg will produce alarm.
- Maximum allowable + 450 mmHg.

7.17.7 Filter Pressure Drop (∆P Filter)

- It represents the difference between the return (outflow) pressure and the filter (prefilter) pressure and reflects the pressure conditions in the hollow fibers
- Filter Pressure Drop (∆P Filter) = Filter Pressure — Return Pressure

7.18 Troubleshooting of CRRT machine pressures alarms:

7.18.1 The vast majority of alarms are associated with one of the circuit pressures is getting out of the range and if not corrected will lead to blood pump stop.

7.18.2 (Refer to Appendix 7).

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Monitoring Tool for Staff Performance on Continuous Renal Replacement Therapy Management:

Goal: To monitor staff's compliance to the management of Continuous Renal Replacement Therapy Management guideline.

	Criteria	Yes	No
1	Hemodialysis consent documented in the electronic medical records (Cerner).		
2	Potassium bath of dialysate and replacement fluid recorded in the dialysis order.		
3	Whether anticoagulation used or not recorded in the dialysis order		
4	CRRT initiated within two hours from order time in Cerner.		
5	Interruptions to treatment and downtime (time during which CRRT is not being delivered to the patient) is documented in Cerner		
6	The life span of the CRRT circuit is more than 48 hours		

Outcome measure (Quality Indicator):

- CRRT catheter related infection rate.

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Appendix 1:

CRRT Order

Order	Comment
Date and time of starting CRRT	
Duration	Enter continuous if not planned for certain hours.
Mode of CRRT	☐ SCUF ☐ CVVH ☐ CVVHD ☐ CVVHDF ☐
Priming Solution	☐ 0.9% Na Cl 1 L with 5000-units Heparin plus 1 L 0.9% Na Cl without heparin. ☐ 0.9% Na Cl 2 L with 5000-units Heparin. ☐ 0.9% Na Cl 2 L without Heparin.
Filter type and size	Usual size: 1.0-1.5m^2 filter. M150 or any special filter like OXIRIS
Anticoagulation	☐ No anticoagulation ☐ Systemic anticoagulation
Dialysate and fluid replacement solution	*Ready-made solution (Prismasol or similar):* Usual composition: • Na: 140 mmol/L. • Cl: 109 mmol/L. • Mg: 0.5 mmol/L. • HCO_3: 35 mmol/L *K concentration (bath):* check the desired: ☐ 0 mmol/L ☐ 2 mmol/L ☐ 4 mmol/L
Blood flow rate (QB): ml/min	• Usually 150-350 ml/min
Dialysate flow rate (QD) ml/Hr.	• In CVVHD and CVVHDF: usually set at 1000-5000 ml/Hr. • In CVVH and SCUF: it is set at zero.

Replacement fluid flow rate (QR): ml/Hr.	• In CVVH and CVVHDF: usually set at 500-3000 ml/Hr. o Pre-filter (QPre): usually 1/3 of fluid replacement. o Post-filter (QPost): usually 2/3 of fluid replacement. • In CVVHD and SCUF: it is set at zero.
Ultrafiltration rate (UFR): ml/Hr.	• Usually 0-500 ml/Hr according to target fluid balance and hemodynamic of the patient. • Assess the fluids balance and adjust the target of fluid balance every 8 hours.
Laboratory monitoring.	• Urea and electrolytes: Na, K, Cl, HCO_3, Ca, PO_4, Mg every 8 hours. • CBC and creatinine every 24 hours.

Appendix 2

Filtration fraction (FF)

Filtration fraction refers to the fraction of fluid removed from the plasma at the level of the filter through filtration. The higher the filtration fraction, the higher the blood concentration at the end of the hemofilter and increase the risk of filter clotting. Most modern CRRT machines calculate filtration fraction but also it can be calculated by using the following formula:

$$FF(\%) = \frac{Total\ ultrafiltration}{Qplasma + Qpre}$$

$$FF(\%) = \frac{Qpre + Qpost + patient's\ ultrafiltration\ (Quf)}{(1 - Htc) \times Qblood + Qpre}$$

Filtration fraction should be monitored and calculated especially in CVVH and CVVHDF modes. Ideally, it should be kept below 25% to avoid filter clotting.

Filtration fraction can be lowered by any of the following steps:

- Increasing the blood flow rate: most effective without affecting the dialysis rate or fluid removal.

- Reducing the post-filter fluid replacement (Q post): it may affect the dialysis dose and therefore needed to be compensated by increasing pre-filter fluid replacement (Q pre) or increasing the dialysate rate in CVVHDF mode.
- Reducing the patient ultrafiltration (Quf), which may result in fluid accumulation.

Abbreviations:

- Q-plasma: plasma flow rate.
- Htc: hematocrit.
- Q-blood: the blood flow rate (liter/hr.)
- Q-pre: Pre-filter fluid replacement (liter/hr.).
- Q-post: post filter fluid replacement (liter/hr.).
- Q-uf: the ultrafiltration rate from the patient (liter/hr.).

Appendix 3

CRRT hourly fluid balance calculations:

To maintain fluid balance, the CRRT dialysis nurse has to set the hourly fluid ultrafiltration rate in CRRT machine (within the range entered in nephrologist's order) to achieve the desired net fluid removal rate per hour as specified by ICU and nephrology team to achieve the fluid balance goal over 24 hours.

$$\text{Hourly UFR (set in the CRRT manchine)} = \text{Hourly desired net fluid removal rate} + [\text{hourly input} - \text{hourly output}]$$

Example:

The desired fluid balance is negative balance by 1.2 liter over 24 hours = Hourly desired net fluid removal rate is 50ml/hour

The patient has the following input and output fluid data:

Input:

- IV normal saline 50 ml/ hour,
- Fentanyl infusion (2000 mcg in 100 ml of normal saline) running at 5 ml/hr.,

- Midazolam infusion (100 mg in 100 ml of normal saline) running at 5 ml/hr.
- Noradrenaline infusion (6 mg in 100 ml of normal saline) running at 5ml/hr.
- Enteral feeding at 60 ml/hr.
- The patient is receiving 300 ml blood transfusion today.
- The patient receives an average of 300 mls of water boluses for medication administration during a 24-hour period.

Output:

- Hourly urine output 10 ml/hour
- Hourly surgical drain10 ml/hour

The target Net fluid removal rate is 50 ml/hour to achieve 1.2 liter per 24 hours:

- Hourly input = {(50 + 5 + 5 + 5 + 60) + {(300+ 300) ÷ 24 }= 150 ml/hr.
- Hourly output = 10 + 10 = 20 ml/hour
- Hourly fluid balance = intake - output= 150 – 20 = 130 ml/hr.
- Set CRRT machine ultrafiltration rate at= 130 ml/hr + 50 ml/hr = 180 ml/hour.

Appendix 4

Intake-Output Chart for CRRT Ultrafiltration record:

Date:

Patient Name: HC Number:

Bed number: Date of CRRT Start:

Date of Current Filter in use: CRRT Modality

Dialysate flow rate:

Pre-filter replacement rate:

Post-filter replacement rate:

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Time	Hourly Intake (A): IV & oral fluid and medications.	Hourly output (B): Urine +drain+ etc.	Hourly Actual fluid removal (UF) rate by the machine output (C)	Hourly Net fluid balance (Net fluid removal) (D)= A-[B+C]	24 hours Net cumulative UF (E= Sum of D)
06:00					
07:00					
08:00					
09:00					
10:00					
11:00					
12:00					
13:00					
14:00					
15:00					
16:00					
17:00					
18:00					
19:00					
20:00					
21:00					
22:00					
23:00					
24:00					
01:00					
02:00					
03:00					
04:00					
05:00					

CRRT Nurse Name: Corporation No:

Appendix 5

Management of acid-base disturbances and electrolytes depletion during CRRT.

Abnormality	Management
Alkalemia • With high serum HCO_3.	▪ Consider reducing the dialysis dose if possible. ▪ Consider 0.9% or 0.45% saline infusion either through separate IV infusion or as fluid replacement.
Acidemia • With low serum HCO_3.	▪ Consider increasing the dialysis dose if possible. ▪ Consider sodium bicarbonate infusion either through separate IV infusion or as fluid replacement (150 mEq of NaHCO3 in 850 ml sterile water or D5%W).
Hypokalemia • Target serum K is 4.0-5.1 mmol/L. • Recheck serum K one hour after each infusion and repeat the dose until serum K ≥ 4 mmol/L.	▪ Serum K 2.2-2.5 mmol/L: give IV KCL 50 mEq in 500 ml normal saline over 5 hours. ▪ Serum K 2.6-3 mmol/L: give IV KCL 30 mEq in 300 ml normal saline over 3 hours. ▪ Serum K 3.1-3.5 mmol/L: give IV KCL 20 mEq in 200 ml normal saline over 2 hours. ▪ Serum K 3.6-3.9 mmol/L: give IV KCL 10 mEq in 100 ml normal saline over 1 hour.
Hypophosphatemia • Target serum phosphorus is > 0.85 mmol/L • Recheck serum phosphorous one hour after each infusion and repeat the dose until its level ≥ 0.85 mmol/L	▪ Serum Phosphorous 0.32-0.52 mmol/L: give IV sodium phosphate 20 mmol in 250 ml normal saline over 4 hours. ▪ Serum Phosphorous 0.53-0.71mmol/L: give IV sodium phosphate 15 mmol in 250 ml normal saline over 4 hours. ▪ Serum Phosphorous 0.72-0.85mmol/L: give IV sodium phosphate 10 mmol in 250 ml normal saline over 4 hours.
Hypomagnesemia • Target serum magnesium is > 0.65 mmol/L • Recheck serum Mg one hour after each infusion and repeat the dose until its	▪ Serum Mg less than 0.41 mmol/L: give IV 4gram Mg sulfate in 100 ml normal saline over 2 hours. ▪ Serum Mg 0.41-0.49 mmol/L: give IV 3gram Mg sulfate in 100 ml normal saline over 1.5 hour. ▪ Serum Mg 0.50-0.60 mmol/L: give IV 2gram Mg sulfate in 100 ml normal saline over 1 hour.

level ≥ 0.65 mmol/L	▪ Serum Mg 0.61-0.64 mmol/L: give IV 1gram Mg sulfate in 100 ml normal saline over 30 minutes.

Appendix 6

Dysnatremia correction:

I. Hyponatremia

- Management of hyponatremia in CRRT patient by administering dextrose 5% in a separate or post-filter return line to avoid rapid correction of hyponatremia and osmotic demyelination syndrome.
- The estimated post-dilution infusion rate of dextrose 5% when using a 140 mmol/L of sodium dialysate/replacement fluid can be approximated by this formula:
- Dextrose 5% infusion rate = [(140 –target Na)/140] x desired clearance
- For example, using post-dilution CVVHDF in a patient with initial sodium of 120 mmol/L with target serum sodium concentration of 130 mmol/L at a desired clearance dose of 3 L/hour using dialysate /replacement fluid with 140 mmol/L of sodium. The dextrose 5% infusion rate would be [(140-130)/140]x3L = 0.214 L/hour (214 ml/hour). So, the post-filter replacement dextrose 5% would be 214 ml/hour and the dialysate/prefilter replacement fluid flow rate should be 2786 ml/hour (3L-0.214L=2.786 L/hour).

II. Hypernatremia:

- Management of hypernatremia in CRRT patient by administering hypertonic saline 3% in a separate or post-filter return line to avoid rapid correction of hypernatremia and/or worsening of cerebral edema by using the standard 140 mmol/L dialysate or replacement fluid.
- The estimated post-dilution infusion rate of hypertonic saline 3% when using a 140 mmol/L of sodium dialysate/replacement fluid can be approximated by this formula:
- Hypertonic saline 3% infusion rate = [(Target Na-140)/(513-140)] x desired clearance

- For example, in a patient with an initial serum sodium 170 mmol/L with target sodium concentration of 160 mmol/L at a desired clearance of 2.5L/hour. The 3% hypertonic saline infusion rate would be [(160-140)/(513-140)]x2.5L= 0.134L/hour (134ml/hour). So, the post-filter 3% hypertonic saline replacement rate would be 134 mL/hour and the dialysate/pre-filter replacement fluid flow rate should be 2366 ml/hour (2.5L-0.134L=2.366 L/hour).

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Appendix 7

Troubleshooting of CRRT machine pressures alarms

Alarm	Possible causes and
Low Access (arterial lumen) Pressures	• Blood flow rate is set to high: Reduce blood follow. • High resistance to flow between the patient and the blood flow pump: o Catheter or line is obstructed. ▪ Kinked Catheter or line: inspect the line. ▪ Patient position: reposition ▪ Clots: aspirate both lumens ▪ Malpositioned: rotate or pull out slightly o Hypovolemia • If still no better reverse the lumens (but will increase recirculation).
High Return (venous lumen) Pressures	• Catheter or line is obstructed: o Kinked catheter or line: inspect the line o Patient position: reposition o Clots: aspirate both lumens o Malpositioned: rotate or pull out slightly • If still no better, reverse the lumens.
High Filter pressure	• Look for other high-pressure alarms o If return pressure also high, indicates a problem might be in the return limb of the circuit and not the filter. o If only filter pressure is high, then problem is in the filter. • Indicates high resistance or excessive flow distal to the blood pump: o Clogging or clotting filter: Plan circuit replacement. o Clotting return limb of circuit: Optimize anticoagulation and/or plan circuit replacement. o Excessively high fluid replacement rate: Reduce the rate.
Rapid rise in TMP	• Dialysate (green) line is occluded by a clamp or kink: o Remove the kink or unclamp the line or bag. • Excessive ultrafiltration relative to blood flow rate: o Reduce ultrafiltration. • Replacement fluid rate too high for the filter size o Reduce replacement fluid rate.
Gradual rise in TMP	• Without an increase in filter pressure drop: filter is clogging: o Plan circuit replacement. o In CVVH: Increase pre-filter fluid rate. • With an increase in filter pressure drop: filter or circuit is clotting: o Optimize anticoagulation. o Plan circuit replacement. o In CVVH: Increase pre-filter fluid rate. o Rinse filter (pre-dilution flush). o Optimize filtration fraction (see appendix 4)

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Addendum One: Procedure for Priming Circuit

	Prismaflex Specific	Key Points
1.	• Review baseline blood work as per Nephrologist CRRT order. • Notify Nephrology Technician when initiating CRRT Therapy • Wash hands prior to all procedures as per policy • Priming at the bedside is preferable to maintain scale integrity • Collect equipment: 1. CRRT hemofilter kit 2. (3) X 1 L bags of 0.9% NaCl 3. Heparin 1,000 unit/ml vial (5ml) 4. CRRT solutions (as per nephrologist order) 5. Dressing tray 6. 20 ml syringe or 50 ml syringe	Ensure adequate supplies ordered Ensure blood work processed Check all products for expiry dates. Solutions and Additives: • Maximum K^+ added to CRRT solutions is K^+ 4 mmol/L added to Prismasol 0. Caution: The venous port should not be used for infusion of inotropes or blood products, except under emergent situations or absolute inability to establish alternate access.
2.	Prepare Priming solution. • Heparin prime for all patients, except patients with Heparin Induced Thrombocytopenia (HIT) or bleeding risk. • Add 5,000 IU heparin (1,000 unit/ml) in one litre 0.9% saline as per nephrologist order. • If 2 litres is required for priming: use	• Heparin binds/adsorbs to the filter fibers to assist and prolong filter life span. • Priming ensures the removal of any air bubbles (air bubbles can precipitate clotting) and debris. It also removes any residues from ethylene oxide which is used for CRRT kit sterilization.

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	plain normal saline in the first bag and heparinised saline in the last bag.	
3.	<u>Prepare Anticoagulant:</u> Unfractionated heparin: • Prepare heparin syringe as per nephrologist order. • Heparin bolus dose 2000-2500 units (1,000 unit/ml) • Heparin maintenance dose = 5-10 units/kg/hr A. <u>Using 20 ml syringe:</u> Add 10,000 units of unfractionated heparin (1000 unit/ml) with 10 ml normal saline in a 20 ml syringe to make a final heparin concentration as (500 units per ml). OR B. <u>Using 50 ml syringe:</u> Add 10,000 units unfractionated heparin (1000 unit/ml) with 40 ml normal saline in a 50 ml syringe to make a final heparin concentration as (200 units per ml).	• In Heparin Free dialysis: draw up 20 ml syringe of 0.9% NaCl without Heparin, for the syringe pump holder and label appropriately. • Caution: Use the syringe pump NOT the peripheral blood pump for the delivery of Heparin. ECMO & CRRT: Anticoagulation is only infused through the ECMO circuit and is managed by ECMO Specialist. • Use either 20 ml syringe or 50 ml syringe for heparin preparation depending on the installed syringe holder in your Prismaflex machine. • The minimum volume of heparin that can be administered via Prismaflex CRRT syringe infusion pump: 1. Using 20 ml syringe is 0.5 ml/hr upto 5 ml/hr and increment by 0.1ml/hr.

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	<u>Calculation of Heparin Infusion rate by Prismaflex</u> syringe pump: <u>For example: in 80 kg patient:</u> If hourly heparin dose (5 unit/kg/hr) = 5 units X 80 kg = 400 units/hr. A. Using 20 ml syringe (final heparin concentration 500 units per ml).: Heparin volume to be infused per hour (mL/hour) = hourly heparin dose/500 = (400/500) = 0.8 ml/hr or B. Using 50 ml syringe (final heparin concentration 200 units per ml).: Heparin volume to be infused per hour (mL/hour) = hourly heparin dose/200 = (400/200) = 2 ml/hr	2. Using 50 ml syringe is 2 ml/hr upto 20 ml/hr and increment by 0.1ml/hr.
4..	Turn ON Prismaflex machine. Machine self-tests. First screen verifies software version	
5.	Once the Prismaflex machine has booted up Select “Continue”	
6.	On "Choose Patient Screen": Select "Same Patient" - Continues same	Caution: If circuit is turned off before priming and prime test complete, you select "same patient" when the machine is turned back on. If you select

	treatment and retains treatment history data. OR Select "New Patient": • Do Not put in patient identifiers (i.e. MRN #). Choose ENTER only, on screen keyboard • Enter weight in kg (Round number to nearest weight in kg) • Enter patient's Hematocrit (Default is 30%) • Select Confirm and confirm patient information	"New Patient" you are unable to operate the machine unless the circuit is unloaded. Select "Load", then "Unload", remove bags from scales and begin again. Caution: If machine turned off after priming complete, Query Screen appears. Machine was not in Treatment Complete Screen when last turned off. Select Continue. Not a new patient.
7.	Choose Therapy: • ALWAYS select CVVHDF mode	Regardless of the mode ordered for the patient, the top right corner of the screen will always read CVVHDF if primed in CVVHDF. Choosing CVVHDF allows access to all pumps and scales. Failure to prime in CVVHDF mode will limit therapy choices once patient is connected. Ensure nothing is hanging on the scales.
8.	Choose Anticoagulation Method: • Follow screen prompts for loading anticoagulation syringe • Screen reads "Systemic anticoagulation (e.g., Heparin), Prismaflex Syringe pump" Select Confirm Systemic Anticoagulation The therapy and anticoagulation choice will come up. This is the opportunity to review and change what you have programmed thus far. Select "Continue"	Caution: If Heparin not required use 0.9% NaCl in 20 ml syringe. Set Heparin pump to 2 ml/hr Another option is "No anticoagulation" which means that you are disabling the syringe and Not able to use the heparin syringe at all unless you start a new treatment. This is not an optimal option.

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9.	Loading Circuit Components: • Select appropriate filter as per Nephrologist order • Place circuit on machine and ensure it is snapped in firmly (black wings visible) • Load Filter Set: Follow instructions on display to load filter set. Ensure all lines are unclamped. Select Load.	CAUTION: In all future screens, touch each bullet in sequence for visual reference to prevent missed steps. Each bullet provides a visual display to follow.
10.	Confirm set loaded: Screen will read the filter set. Confirm set	• The bar code reader scans the bar code label on the filter • If the bar code reader does not identify the filter set, you can still use it. You need to manually enter the filter set type you have loaded and confirm.
11.	Prepare and connect solutions: Follow screen prompts. (Do not route lines) • Break seal to mix compartment - A into B • Mix solutions very well • Hang CRRT fluid bags • Hang 1 litre of heparinized saline on the left corner hook. • Apply co-signed medication label	Touch each bullet in sequence for visual reference. Caution: When spiking solutions use rubber port only. Ensure the spike port is hanging straight and not kinked. Using the cone port may cause flow problems, fluid imbalances and incorrect weight change alarms. Caution: Do not place 0.9 % NaCl solutions on the Dialysate scale as this can produce a life-threatening fluid/electrolyte imbalance.
12.	Add Blood Warmer Extension tubing (If	Caution: Attach to the return line before deaeration

	using Prismatherm II Blood Warmer) Select Continue	chamber. Caution: Bicarbonate solution produces carbon dioxide when heated, creating extra bubbles, and consequently the possibility of more air in the filter system.
13.	Install Syringe Screen: Follow screen prompts • Install the anticoagulant syringe Select Continue and Confirm	Touch each bullet in sequence for visual reference. Use only Luer lock 20 ml syringe Ensure the proper label is attached to the syringe (heparin or normal saline)
14.	Verify Set Up Screen: Follow screen prompts In Prismaflex with Software 7.11 you will have an option "prime" or prime + test. This would take the priming solution required by the machine (i.e 500 ml or 1L or 2L) and then it would go into prime test without having you to press Prime Test. As it is important to flush out the Heparin prime. Select Prime	Caution: Observe filter set closely for leaks. If leak cannot be stopped by tightening connections - do not use the filter set (Press Stop and follow instructions to Unload set)
15.	"Priming 1 of 2 Cycles Complete" Screen: Follow screen prompts Replace Heparinized prime bag with 1 L of 0.9% NaCl and Select "Next Cycle" • Circuits can remain primed for 6 hrs. Label circuit with date and time primed. Document in flow sheet • If a circuit sits stagnant for greater than 30 minutes, it must be re-primed with 1L 0.9% NaCl prior to	Priming Cycle depends on the set loaded. Caution: Once prime test is selected you cannot re-prime. Ethylene oxide, (the sterilizing agent) can collect in the potting fibers and leach into the stagnant normal saline solution and infuse to the patient

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	patient connection. This flushes the potting compounds out of circuit and prevents exposing the patient to these potting compounds. Select "Re-prime" RECOMMENDATION: DO NOT SELECT PRIME TEST UNTIL READY TO CONNECT TO PATIENT Do not adjust the level of the deaeration chamber until after Prime test as the deaeration chamber may become wet - you will be given the option to do this now, wait until after the Prime Test is complete.	causing allergic/anaphylactic reaction "Prime Test Passed" screen reads "No further priming can be done beyond this screen. The screen does give the option to select Re-prime which brings you back to the Re-prime screen. If you do exceed the 30 minutes stagnant circuit time frame and have completed the prime test, this option is available to re-prime set. Once the set has re-primed it then requires the Prime Test to be done again.
16.	If patient is ready for circuit connection: Select "PRIME TEST"	
17.	"Prime Test Passed" Screen: Follow instructions on display. Select Continue Adjust Deaeration Chamber to the level of the purple stripe on the Replacement line Select Continue	The Daeration chamber needs to have enough room above the fluid line to allow for air to escape from the filter set. Failure to keep the fluid level at optimum height may allow air and/or blood clots in the lines.
18.	"Enter Treatment Settings" Screen: Set Excess Patient Fluid Loss/Gain Limit: For example: (100-400) ml over 3 hrs (If the limit is reached CRRT machine will end the treatment) Select "Confirm"	Excess Patient Fluid Loss/Gain Limit: protects the patient from unintended fluid loss or gain that coud lead to major complications and death.

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19.	Enter Flow Rates Setting Screen Refer to Procedure for Connecting to Patient (Addendum 2)	

Addendum two: Procedure for Connecting to Patient

	Important Steps	Key Points
1.	All HCP's will wear appropriate Personal Protective. If Tego Connector present on CRRT catheter lumens, use aseptic technique. If no Tego Connector present on CRRT catheter lumens use sterile technique to access lines.	
2.	Consult MD re: CRRT can be started. Ensure cardiac arrest cart is present for patient connection and CRRT initiation.	Caution: In the event of a cardiac arrest, turn the CRRT machine off and disconnect patient.
3.	Caution: Double check ordered solutions are hung on the correct scales	
5.	• Clean patient CRRT catheter Access and Return lumens with Chlorhexidine. • Unclamp patient CRRT catheters - aspirate 2-3 mls to remove Heparin in dialysis lines and flush with normal saline to ensure patency and minimal resistance through lines. Prevents patient from receiving excess Heparin. • Clean Circuit Access and Return lines. • If doing a Clear Prime (with saline), follow Screen Prompts after Prime Test is done • If doing a Blood Prime, press Stop.	
6.	Enter Treatment Settings: Start at Blood Flow Rate = 50 ml/min until circuit is fully primed	Do not start ultrafiltration or

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	Important Steps	Key Points
	with blood and increase gradually to reach target Blood Flow Rate within 5 minutes. Initially Set Fluid Removal Rate = 0 ml/hr And Set Replacement/Dialysate Rates = 0 ml/hr Once you reach the target Blood Flow Rate: • Enter Pre Blood Pump (PBP) Flow Rate ordered (pre-filter replacement) • Enter Dialysate Flow Rate ordered • Enter Replacement Flow Rate ordered • Press Pre or Post (therapy defaults to Post filter). • Enter Fluid Removal Rate as per nephrologist order Press ENTER after all flow are set.	dialysate flow until the target blood flow is reached. All treatment settings are obtained from the Nephrologist order in Cerner .
7.	Enter Anticoagulation Settings by select Anticoagulant button on the top of the screen. Enter ordered anticoagulant rate (bolus and maintenance) Select "Confirm" Review Prescription Screen and change as needed Select "Continue"	
8.	Immediately prior to Patient Connection: Administer a Heparin bolus to patient as per nephrologist order if not doing a blood prime,	Do not administer Heparin for HIT patients.
9.	"Connect Patient Screen": Follow instructions on display. Touch each bullet in sequence for visual reference • Connect Circuit Access line to patient catheter Access lumen • Connect Return line to patient catheter Return lumen	Refer to Procedure for Connecting to ECMO (Addendum 3) Monitor for air returning to

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	Important Steps	Key Points
	• Connect Effluent line to Effluent bag • Unclamp all patient and circuit lines. • Clamp all unused line and very correct setup. press "START" to begin treatment.	patient through the Return line. If air observed Select "Stop" and disconnect Return line from patient catheter. Briefly start blood pump to remove air. Reconnect to patient.
10.	Once patient hemodynamically stable, program ordered treatment settings are reached: Start Blood Warmer. Monitor core temperature continuously.	
11.	Have an independent double check of programmed treatment settings, as per CRRT Nephrologist orders.	

Addendum Three: Procedure for Connection to ECMO Circuit

- This section will need to be specific for your ECMO circuit. Perfusionist to check placement of lines in relation to their circuit if vascular access catheter is not being used for CRRT circuit connection.

	Important Steps	Key Points
1.	*For all patients on ECMO, obtain order for blood primed circuit Do not add any Blood Warmer or extension tubing. Do not give initiation bolus of heparin when introducing CRRT circuit into ECMO circuit. For all patients with separate CRRT access: • After blood prime completed, patient can be placed onto CRRT circuit as per normal procedures.	From Prismaflex Software 7.11 does not require that you select "access pressure positive or negative" during the priming procedure Heating/cooling occurs through the ECMO warmer. All anticoagulation runs via ECMO circuit.

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	Important Steps	Key Points
	• Consult MD re: CRRT can be started. • Walk through of procedure should be completed with perfusionist responsible for ECMO circuit prior to initiating CRRT on patient.	
2.	IF patient does not have separate access for CRRT: ECMO Perfusionist will connect CRRT Access line to a port on the ECMO circuit.	1. Connect inflow (Access) for the CRRT to the Luer lock on the outlet port of oxygenator and outflow (Return) for CRRT to the Luer lock on inlet port of the oxygenator. OR 2. Connect the inflow (Access) for the CRRT machine to the arterial line, near to the Return cannula of the ECMO circuit and the outflow (Return) connecting to the ECMO circuit near the drainage cannula before the ECMO pump. OR 3. Connect the inflow (Access) for the CRRT circuit to the venous line, just after the ECMO pump and the outflow (Return) is connected to the ECMO circuit just before the oxygenator.

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	Important Steps	Key Points
3.	Heparin infusions are run via the ECMO circuit NOT via the CRRT circuit and aPTT is managed by the ECMO Specialist/Perfusionist. Place 0.9% NaCl syringe on the Prismaflex Syringe pump.	Heparin not to run in stopcock where CRRT access line attached to ECMO circuit.
4.	100 mls of post dilution fluid still needed on the Replacement Scale to protect the deaeration chamber (fluid interface between blood and air).	
5.	CAUTION: Ensure CRRT circuit is removed from ECMO circuit prior to any trial off ECMO. When the ECMO circuit is isolated from the patient by "clamping off ECMO" the CRRT circuit can create a negative pressure in the ECMO circuit and potentially draw in air from the oxygenator into the circuit. This will cause the ECMO circuit to fill with air.	

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Addendum four: Disconnection from CRRT - Returning Blood to Patient

	Important Steps	Key Points
1.	• Hang 500ml bag of 0.9% NaCl on a hook (not on scale). • Attach the access line to bag of normal saline. • Soft keys. End treatment. Return blood: Follow instructions on screen (Auto Return/Manual Return). • If return manually, depress soft key until appropriate volume delivered. Continue with disconnection.	Can return blood by CRRT circuits as long as the filter is NOT clotted by selecting END Treatment screen and return blood. Consider how much volume patient can tolerate. Discuss with nephrologist the appropriate volume to be returned to patient.
2.	Blood Flow Rate can be set up to 100 ml/min	
3.	Clean the patient's catheter Access and Return sites using sterile technique. Allow Chlorhexidine solution to dry for 60 seconds.	
4.	Stop the Blood Pump	
5.	Clamp the Access catheter and remove the Red Access line and connect it to the bag of saline at the spike adapter. Leave the Return line attached to the patient.	
6.	Press Start or Continue and let the machine run until the circuit clears the blood in the tubing and filter to the patient.	
7.	Press Stop. End Treatment • Discontinue the venous line from the patient • Lock the CRRT catheter lumens as per nephrologist order.	

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	Important Steps	Key Points
8.	Recirculation: • Involves returning blood to the patient; temporarily disconnecting patient (e.g going for CT scan) and recirculating saline through the blood lines. • Maximum recirculation time is 2 hours. Once the blood is returned to the patient, press CONTINUE. Follow instructions on display. Press START RECIRC softkey. Enter the preferred Recirculation rate 50-100 ml/min Once the patient is ready to be reconnected, Re-prime the circuit, and reconnect the patient. Resume treatment by pressing the START softkey on the Reconnect Patient screen.	• The length of time spent in recirculation will be included in the filter life. • Recirculation is ONLY performed when: 1. The filter is less than 24 hours old. 2. The filter is free of clots