Guideline

Use of Continuous Veno-Venous Haemofiltration (CVVH) and Continuous Veno-Venous Haemodiafiltration (CVVHDF) within Paediatric Intensive Care Unit (PICU)

1 Scope

For use within PICU (paediatric intensive care unit).
This guideline is not applicable to adult areas or any low dependency area within children's services and neonatal services.

2 Definitions

ABG	Arterial Blood Gas
CRRT	Continuous Renal Replacement Therapy
CVL	Central Venous Line
CVVH	Continuous Veno-Venous haemofiltration
CVVHDF	Continuous Veno-Venous haemodiafiltration
FBC	Full Blood Count
HAS	Human Albumin Solution
iCa	Ionised Calcium
LFT	Liver Function Tests
PBP	Pre Blood Pump

3 Introduction

The purpose of this guideline is to provide support and direction to staff members when caring for a child requiring CVVH or CVVHDF via the Baxter Prismaflex/ Prismax machine.
This guidance is based on and acknowledges the guideline used at Nottingham University NHS Foundation Trust.

4 Undertaken by (staff groups)

The management of CVVH and CHHHDF should only be undertaken by medical and nursing staff trained and agreed as competent to do so.

5 Executive summary of guideline

Patient requires **CVVH/CVVHDF**

First line **anticoagulation** on PICU is **Citrate**; consider using heparin anticoagulation if any of the following contraindications present:

- Patients with hepatic failure (as the Calcium-Citrate complex is metabolised by the liver) as in:
  - Severe Liver Disease
  - Baseline INR >3.5
  - Paracetamol hepatitis with gross elevation of AST, INR and with elevated lactate
- <1 year of age
- Clinical risk of bleeding considered too great for ANY CRRT anticoagulation
- Previous Citrate accumulation, if organ dysfunction persists
- Additional Citrate load e.g. on-going massive transfusion

Prior to commencing therapy:

- Obtain a full set of bloods, paying particular attention to electrolytes
- It is not necessary to have cross matched blood available before commencing therapy and should not be a reason for delay, unless there is a clinical reason for the patient to have a blood transfusion prior to starting.
- Ensure appropriate size VasCath is insitu
- Complete prescription chart
- Assemble PrisMax and all necessary equipment

The following groups of patients require extra consideration:

- Low body weight
- Septic (section 13)
- Hyperammonaemia or other Metabolic Emergency **(Time critical)**, Hyperkalaemia, Hyperuraemia or Hypernatraemia (see clearance chart in section 10) for information on adjusted flow rates)

Use Epic order set and flowsheets

Prescribing checklist:

- Heparin line lock
- Priming fluids – 1st prime: 0.9% Sodium Chloride with Heparin, 2nd prime: 0.9% Sodium Chloride
- Pre Blood Pump, Replacement and Dialysate fluid bags
- Flow rates
- Fluid removal rate
- Calcium Gluconate infusion
- When on Citrate, please indicate Calcium compensation algorithm arm required (with consideration for liver impairment)

Considerations during therapy:

Initiating therapy:
Haemodynamic stability
Fluid balance
Electrolytes: pay close attention to Mg^{++}, PO_4^- and K^+
Drug clearance
Temperature control

Potential problems:
Fluid & electrolyte shift
Citrate accumulation
Infection
Air embolism

Monitoring during therapy:
Arterial blood gas within 1hr of commencing then every 4hrs thereafter
U&Es 6hrs after commencing then every 6hrs thereafter
FBC daily

Additional Monitoring during therapy:
Citrate: Filter Ca and Patient Ca within 1 hour of commencing then 4 hourly once stable (See algorithm on pg 23); T:i ratio every 6hrs; Clotting every 12hrs; More frequent bloods may be required in those at risk of Citrate accumulation
Heparin: Hourly ACTs; Clotting frequency required

6 Introduction and description of therapies

Continuous renal replacement therapy (CRRT) is a supportive therapy used for the management of fluid balance and metabolic derangement, with or without evidence of acute injury kidney injury (AKI), in critically ill patients.

Aims of the therapy include:

- Maintaining fluid balance
- Removing excess urea & creatinine
- Correcting and maintaining metabolic and electrolyte balance
- Removing toxins

Indications for commencing treatment:

- Fluid overload
- Electrolyte imbalance- particularly hyperkalaemia
- Acute Kidney Injury (AKI)
- Sepsis
- Anuria
- Uraemia
- Inborn errors of metabolism
- Rhabdomyolysis
- Tumour lysis
- Drug intoxications

This guideline focuses on the use of Continuous Veno Venous Haemofiltration (CVVH) and Continuous Veno Venous Haemodiafiltration (CVVHDF); these are both delivered using the Prismaflex/ Prismax machine (Baxter)

Using a dedicated double lumen vascath (see Sizing Guide) and an extracorporeal circuit, blood is continuously removed and returned to the patient. This continuous technique allows fluid and waste products to be removed gradually over a 24 hour period. This provides more haemodynamic stability for critically ill children who are often cardiovascually unstable.

The extracorporeal circuit incorporates a blood pump and a filter containing a semi-permeable membrane. A pressure gradient within the circuit forces fluid and solutes across the membrane to form effluent fluid. Dialysis fluid can also be added to the other side of the filter,causing molecules to move across a concentration gradient. The processes utilised are ultrafiltration, convection and diffusion

6.1 Filtration processes

6.1.1 Ultrafiltration

This is the movement of fluid through a semi-permeable membrane driven by a hydrostatic pressure gradient. On the Prismaflex/ Prismax a positive pressure is generated by the blood pump on the blood side of the semi-permeable membrane and a negative pressure by the effluent pump on the other side. This results in the movement of fluid from the positive pressure side (blood side) to the negative pressure side.

6.1.2 Convection

This occurs when large volumes of fluid crossing the semi-permeable membrane down the hydrostatic pressure gradient cause solvent drag across the membrane. Large molecules can be moved efficiently if the flow is fast enough. Pre blood pump and replacement fluid is added to the circuit to increase the flow across the semi-permeable membrane.

6.1.3 Diffusion

This is the movement of solutes across a semi-permeable membrane caused by a concentration gradient. Solutes move from an area of higher concentration to an area of lower concentration. On the Prismaflex/ Prismax this is achieved by the addition of dialysate fluid on the other side of the semi-permeable membrane. This is run counter-currently to the blood flow to ensure the concentration gradient is maintained the whole length of the filter.

The movement of molecules in CRRT are driven by the above processes but are limited by the size of the solute particles. The Prismaflex/ Prismax filters have pores that allow passage of molecules up to 35,000 Daltons. This allows for free movement of small ions and molecules (e.g. urea, creatinine, ammonia) across the membrane as well as some larger molecules such as myoglobin (17,200 Daltons), insulin (active) and interleukins (varies). Small molecules are more efficiently removed by diffusion and larger molecules by convection.

6.1.4 Adsorption

Some molecules are removed in CRRT by adherence to the artificial semi-permeable membrane; this is the process by which inflammatory markers are thought to be removed. High levels of these molecules can cause the filter to clog and become less effective.

On PICU using the Prismaflex/ Prismax (Baxter), two modes of CRRT are utilised, these are Continuous Veno Venous Haemofiltration (CVVH) and Continuous Veno Venous Haemodiafiltration (CVVHDF).

CVVHDF is the default mode.

6.2 Continuous Veno Venous Haemofiltration (CVVH)

This mode of CRRT utilises the principles of ultrafiltration and convection and is ideal for removing middle and large molecules.

- Biochemistry is controlled by removing large volumes of filtrate and replacing them with electrolyte containing fluid (replacement fluid). The more filtrate you remove and replace the more efficient haemofiltration is in controlling biochemical disturbance.

- As most solutes are distributed within the extracellular and intracellular fluid compartments (total body water), the volume of filtration (replacement) necessary to control biochemistry relates to total body water. Clinical experience has shown that a replacement of approximately 50% of bodyweight (1kg = 1litre) is usually adequate for solute and electrolyte removal.

6.3 Continuous Veno Venous Haemodiafiltration (CVVHDF)- default mode

This mode of CRRT utilises the principles of ultrafiltration, convection and diffusion; using both convective and diffusive transport systems will optimise the clearance of molecules of varying sizes.

- The addition of dialysate flow with CVVHDF will improve the efficiency of acid base, waste and control of electrolyte balance. Waste and electrolytes diffuse from the patient's blood into the dialysate fluid surrounding the fibres. The "saturated" dialysate fluid (effluent) is removed from the filter and discarded.

- Diffusion is a two way process, molecules that are at a low concentration in the blood and high in the dialysate fluid will diffuse into the blood and vice versa (e.g. bicarbonate).

- Convective transport systems utilised in CVVH are limited by the blood flow achieved. If higher replacement rates are indicated, but not achievable, adding in dialysate flow will optimise clearance. Reasons for not achieving desired replacement rates could be due to patient stability or issues with access limiting the blood flow rates.

- This is practically important when treating children with inborn errors of metabolism, for overdose of drug or therapeutic agents and for patients with a high lactate.

- Increasing dialysate flow will at least theoretically improve clearance; however this is limited by the relatively low dialysate flow rates generated by CRRT equipment.

6.4 Choice of therapy

In general citrate will be the first line anticoagulate

CVVHDF *should always be selected when setting up the* Prismaflex/ Prismax

When performing filtration with heparin or epoprostenol anticoagulation it is possible to switch between CVVH and CVVHDF whilst treatment is running depending on the patient's clinical condition.

However, when using citrate anticoagulation ***CVVHDF*** *will always be the therapy of choice.* This is due to the additional benefits of running dialysate with citrate, such as off-loading citrate into the effluent bag which can help prevent citrate accumulation and reducing high bicarbonate levels in the patient's blood. If therapy is proving to be too efficient you can move the patient down a weight bracket (see table in section 9).

7 Coagulation

As with any extracorporeal circuit, the circuits used for CRRT require the administration of anticoagulation to prevent the development of clots and keep the blood flowing in the circuit. There are two methods of anticoagulation – citrate and heparin. Filter set up is different depending on which anticoagulation method is used. Historically the most common anticoagulant used for CRRT was heparin, which is run as an infusion into the circuit. There has now been a shift to using regional citrate anticoagulation.
Citrate anticoagulation is more beneficial than heparin as it can be used in patients that are at an increased risk of bleeding and have contraindications to heparin. It has also been shown to increase the life of the circuit, resulting in fewer interruptions to treatment and ensuring a more efficient treatment for the patient.

Regional citrate will be the anticoagulation of choice on PICU – prescribing of appropriate medicines / fluids will be via the Epic order set 'Paediatric Citrate Haemofiltration' – see appendix 1

For information on use of the filter with heparin anticoagulation please see Appendix 3

7.1 What is Citrate

Citrates are a family of compounds, but in relation to anticoagulation for CRRT trisodium citrate and citric acid are the two relevant compounds.

The citrate solution used on PICU is Prismocitrate 18/0; this contains trisodium citrate 18mmol/L and 0mmol/L of citric acid.

Trisodium citrate is a salt of citric acid sometimes referred to as sodium citrate. It is metabolised in the liver to bicarbonate. Trisodium citrate also binds with ionised calcium and magnesium.

Sodium citrate is widely used in blood collection tubes and for the preservation of donated blood products. It is now becoming an increasingly popular alternative to heparin for the anticoagulation of the extracorporeal circuits used in CRRT.

7.2 How does citrate work?

In the blood, calcium circulates primarily either in a free form or bound to plasma protein. The free portion, termed ionized calcium (iCa), is the form of calcium which is key to the activation of the coagulation cascade. Through binding and forming a complex with iCa, citrate prevents coagulation in the extracorporeal circuit.

Citrate anticoagulation is referred to as regional anticoagulation as it is delivered to the circuit and filter without anticoagulating the patient, offering a significantly reduced risk of bleeding. However, it is still vital that iCa levels in both the circuit and the patient are closely monitored to ensure adequate anticoagulation of the circuit and minimise risk to the patient.

Citrate solution is delivered to the patient's blood pre-filter, on the pre-blood pump (PBP) scale; this ensures that both the filter and circuit are anti-coagulated. The concentration of citrate added to the patient's blood before entering the filter depends on the blood flow rate and citrate infusion (PBP) flow rate. The amount of citrate is expressed, as citrate dose, in mmol/L blood.

On PICU the starting citrate dose will be 4mmol/L for most patients. A filter iCa concentration of 0.25-0.35mmol/L is required for optimum anticoagulation of the circuit.

For patients with liver impairment/failure consider a lower starting dose of citrate of 3mmol/L. A filter iCa concentration of 0.4 – 0.45mmol/L is required for optimum anticoagulation of the circuit.

See section 9 for how to calculate flow rate of Prismocitrate 18/0 in ml/hr for the citrate dose required

Blood flow rates and citrate infusion rates determine the ionised calcium level in the circuit; if the blood flow rate is adjusted the citrate infusion rate will automatically be altered by the Prismaflex/Primsmax. This synchronization of the blood flow rate and PBP citrate flow rate is necessary to maintain the citrate dose at the desired level.

Citrate also non-specifically binds to positively charged ions such as magnesium and phosphate, so a reduction in serum magnesium and phosphate levels is to be expected. Urea and electrolyte blood samples should be checked at least 6 hourly whilst the patient is on the filter to monitor electrolytes closely and correct any abnormalities

Most of the citrate infused into the circuit is cleared by the filter and lost in the effluent. Consequently, only a portion of the infused citrate is delivered to the patient.

Based on the citrate infusion rate and the rate of citrate loss in the effluent, the amount of citrate delivered to the patient can be calculated. This is called the '**patient citrate load'**. Citrate will be rapidly metabolised by the patient so will not have any anticoagulation effect, however if this citrate is not metabolised this can lead to citrate accumulation, please refer to the 'Citrate accumulation' section for more details on how to recognise and manage this.

7.3 Citrate precautions

- Severe Liver Disease(as the calcium-citrate complex is metabolised by the liver)
    - Patients with severe hepatic failure and INR >3.5
- Patient is aged <1yr as they will have an immature liver
- Paracetamol hepatitis with gross elevation of AST, INR and with elevated lactate
- Clinical risk of bleeding considered too great for ANY CRRT anticoagulation
- Previous citrate accumulation (if organ dysfunction persists)
- Additional citrate load e.g. on-going massive transfusion

If any of these contraindications are present, Citrate anticoagulation can still be used, but must be discussed with the PICU Consultant and must start at a lower dose (3.0mmol/L), monitor iCa and filter calcium closely. In this case, a higher filter calcium can be accepted, please see the algorithm for liver impairment/failure on page 19 for more information.

7.4 Calcium gluconate infusion

A certain percentage of citrate in the blood in the circuit is cleared by the filter and lost in the effluent. This citrate is bound to some of the patient's ionised calcium so in order to avoid systemic ionised hypocalcaemia, a separate infusion of calcium is required, being adjusted to maintain patient ionised calcium levels between 1.0-1.2mmol/L. This infusion is delivered via the Prismaflex/ Prismax syringe pump directly to the patient via a **central** line, not into the circuit. If central access is problematic, then this infusion can be delivered via the return lumen, however this may increase the risk of clots forming within the vascath, so this MUST be discussed with the PICU Consultant beforehand.

Based on the estimated calcium loss in the effluent, the Prismaflex/ Prismax calculates the amount of compensatory calcium to be delivered by the machine syringe pump. This calculation takes into account the concentration of the calcium solution in the syringe.

Calcium compensation is expressed in % and can be modified during treatment. Complete replacement of the calcium lost in the effluent corresponds to a calcium compensation of 100%. The range of calcium compensation is variable and is dependent on the set used, weight of the child and flow rates.

The Prismaflex/ Prismax software calculates the syringe flow rate based on the calcium compensation selected, CRRT dose, patient body weight and calcium concentration in the syringe. The syringe flow rate cannot be set directly. The same applies for the calculation of the calcium rate i.e. the amount of calcium administered per hour.

In Epic a flow rate of 0 – 40 ml/hr for the calcium gluconate syringe should be prescribed, as the actual flow rate being administered will be calculated by the Prismaflex / Prismax software – nursing staff should document on the Epic MAR the flow rate of calcium being administered

On PICU, calcium gluconate will be used for the calcium infusion, see prescription chart for details.

Calcium gluconate concentration

For all patients
40ml of Calcium Gluconate 10% with 10ml Sodium Chloride 0.9% (9mmol/50ml or **0.18mmol/ml**)

Calcium syringe needs to be changed every 24 hours and calcium syringe lines every 72 hours.

Calcium gluconate must be administered centrally, if separate central access is not available then run on return line using a 3-way tap. Monitor Vas Cath closely for signs of clotting and keep filter iCa in lower end of range.

8 Citrate, Dialysate and replacement solution

The fluid bag required for each scale (Pre blood pump, Dialysate and Replacement) will depend on the type of anticoagulation used.

Fluid bags need to be changed every 24 hours.

8.1 For citrate anticoagulation

The Citrate solution used on PICU will be Prismocitrate 18/0 and will be used on the Pre Blood Pump scale:

Prismocitrate 18/0 (all values in mmol/L)									
Sodium	Potassium	Calcium	Magnesium	Chloride	Phosphate	Lactate	Bicarbonate	Glucose	Citrate
140	0	0	0	86	0	0	0	0	18

The Dialysate solution will be Prism0cal B22; calcium-free solutions should be used on the dialysate scale to prevent restoration of ionised calcium levels and coagulation in the filter.

Prism0cal B22									
Sodium	Potassium	Calcium	Magnesium	Chloride	Phosphate	Lactate	Bicarbonate	Glucose	Citrate
140	4	0	0.75	120.5	0	3	22	6.1	0

Phoxilium will be the first line fluid for the replacement scale for patients with phosphate <3mmol/L or glucose >5mmol/L. The use of Phoxilium will aid in the restoration of phosphate lost during filtration. Contains no glucose so close monitoring is essential. Phoxilium contains calcium so the return line should be closely observed for signs of clotting.

Phoxilium									
Sodium	Potassium	Calcium	Magnesium	Chloride	Phosphate	Lactate	Bicarbonate	Glucose	Citrate
140	4	1.25	0.6	115.9	1.2	0	30	0	0

If the patient has a high phosphate (>3mmol/L) then Prismasol 4 is used as a second line option.

Prismasol 4 (all values in mmol/L)									
Sodium	Potassium	Calcium	Magnesium	Chloride	Phosphate	Lactate	Bicarbonate	Glucose	Citrate
140	4	1.75	0.5	113.5	0	3	32	6.1	0

Please discuss any patients with high potassium levels with consultant before commencing treatment.

8.2 Adding electrolytes to fluid bags

With the exception of sodium, no additives should be added to any of the fluid bags.

(for information on how to add sodium to fluid bags used for heparin anticoagulation see appendix 3)

If the patient requires additional phosphate then please discuss this with the consultant and pharmacist. This should then be given as a direct correction to the patient.

In cases of hypernatraemia in patients requiring CRRT it may be necessary to add sodium to replacement/dialysis fluids to ensure sodium correction does not occur too rapidly. The sodium content of Prism0cal B22 and Phoxilium is 140mmol/L, so without the addition there is a significant risk the patients' serum sodium could drop too quickly.

If an addition is required this must be clearly documented on the patients CVVH/CVVHDF Daily Prescription and Record Chart and the patient's serum sodium must be closely monitored. If the patient's plasma sodium is greater than 150mmol/L follow the guidance below for adding sodium (sodium should **NOT** be added to the citrate 18/0 fluid bag):

Target Na^+ (mmol/L)	**Addition to 5 litre bag (Prism0cal B22/Phoxilium)**	
150	10mls of sodium chloride 30%	Remove same volume from replacement/dialysate bag before addition (e.g. for target 150mmol/L remove 10mls from Prism0cal B22/Phoxilium, then add 10mls sodium chloride 30%)
155	15mls of sodium chloride 30%	
160	20mls of sodium chloride 30%	
165	25mls of sodium chloride 30%	
170	30mls of sodium chloride 30%	
175	35mls of sodium chloride 30%	
180	40mls of sodium chloride 30%	
185	45mls of sodium chloride 30%	
190	50mls of sodium chloride 30%	

9 Considerations prior to commencing therapy

9.1 Access

Temporary central venous lines are used for CRRT within PICU.

Tego connectors need to be used on temporary CVL when they are being used for CRRT. Usually on PICU needle free connectors are used on all temporary venous lines, however these do not accommodate the high flow rates required for CRRT. Tego connectors allow flow rates of up to 600ml/minute and provide a reduced risk of catheter related blood stream infections. These must be changed every 7 days whilst the CVL is in situ.

Weight	Type	Size	Line lock
<10kg	**Braun or similar**	2 x 18G (green) peripheral cannula	0.2ml or 1.3ml with connection Heparin 100units/ml
	Gam Cath	6.5Fr x 7.5cm	Lock using volume of line Heparin 100units/ml Prescribe on front of CVVHDF chart
		6.5Fr x12.5cm	
10-20kg	**Gam Cath**	8Fr x 10cm	
		8Fr x12.5cm	
>20kg	**Gam Cath**	11Fr x15cm	
		11Fr x 20cm	

Heparin line lock MUST be aspirated and discarded before connection to patient.

9.2 Prior to connection

Obtain baseline bloods: to include ABG, FBC, U+E, LFT, magnesium, phosphate, total calcium and clotting.

Check the patient's iCa and magnesium levels are within normal limits. When commencing therapy the calcium compensation is usually started at 100%, but if the calcium is out of range:

- If iCa >1.2 start calcium compensation at 90%
- If iCa 1.0 – 1.2 start calcum compensation at 100%
- If iCa <1.0 start calcium compensation at 110%

If patients iCa level is very low consider giving a correction prior to commencing treatment. Also if the patient already has a calcium infusion running then keep this going whilst filtration is established. Once patient's iCa levels are at desired

level the calcium infusion **not** being delivered by the Prismaflex/Prismax can be stopped.

Magnesium levels <0.7 should be corrected (if arrhythmias present then <1mmol/l). This should be done according to unit policy. Discuss with consultant and pharmacist before replacing.

With citrate, effectiveness of anticoagulation is monitored by taking iCa levels from the filter so Activated Clotting Times (ACTs) are not required prior to or during treatment.

9.3 Equipment required

- Prismaflex/PrisMax circuit HF20/ST60/ST100 (see prescription for size guide)
- TherMax disposable if using ST circuit

- 50mL luer lock syringe
- 5 litre bag Prismocitrate 18/0 to be used on the pre blood pump scale
- 5 litre bag Prism0cal B22 to be used on the dialysate scale
- 5 litre bag Phoxilium or Prismosol 4 to be used on replacement scale
- 1 litre bag 0/9% sodium chloride with heparin 2000 units added (nurses to prepare on PICU) for first prime
- 1 litre bag 0.9% sodium Chloride for 2nd prime
- Calcium Gluconate 10% injection and 0.9% sodium chloride for calcium infusion
- Dedicated calcium infusion line
- Ensure at least one adult unit of packed red cells is available in blood bank

To set up the Prismaflex/Prismax for citrate anticoagulation please refer to the citrate anticoagulation standard operating procedure which can be found attached to each Prismaflex/ Prismax. Aseptic non-touch technique should be utilised when setting up and connecting PrisMax.

9.4 Priming

Priming of the circuit will be initially with Heparin 2000 units in sodium chloride 0.9% 1000ml, followed by a 1000ml bag of 0.9% sodium chloride

Blood priming should now **not** be practised, if a patient requires blood please run a **transfusion** prior to or during commencement of therapy.

9.5 Starting parameters

- Always set up in CVVHDF
- Initial starting citrate dose 4mmol/L, only change after discussion with consultant.. See section 9 for how to calculate flow rate of Prismocitrate 18/0 in ml/hr for the citrate dose requied
- If patient's iCa within normal range start calcium compensation at 100%
- Due to the blood pump speed being considerably slower than previously used, there is no need to commence treatment at half the blood pump speed for patients <50kg.
- For patients >50kg you may want to start at a lower blood pump speed and build up when the patient is haemodynamically stable.

9.6 Unintended patient fluid loss or gain limit

This is the difference between the fluid removal measured on the machine and the set fluid removal rate over the last 3 hours. Once this limit has been reached the Prismaflex/Prismax will stop and treatment will not be able to continue. The default limit is 60-400mls over 3 hours, but should be set based on patient's weight, clinical condition and haemodynamic stability.

10 Flow rates

These settings are a guideline only - final setting should be agreed with supervising PICU consultant.

Initial Treatment Settings						
	<5kg	**5-11kg**	**11-18kg**	**18-30kg**	**30-50kg**	**>50kg**
Blood flow rate	20ml/min	30ml/min	55ml/min	3ml/kg/min		
Pre blood pump citrate	Starting dose: 4mmol/L Adjust during treatment according to algorithm in liver impairment or <1yr, start at 3mmol/L and monitor systemic iCa closely					
Dialysate	Commence at 20ml/kg/hr (can increase to 50ml/kg/hr)					
Replacement	20ml/hr	30ml/hr	50ml/hr	100ml/hr	150ml/hr	200ml/hr
Calcium syringe	Initially start at 100% if patient calcium normal. Adjust during treatment according to algorithm.					
Set patient gain/loss limit	This is set at 10ml/kg over 3 hours, once set this limit cannot be changed during treatment.					

These are initial flows for commencing treatment and can be altered depending on patient's condition. For example: if the patient has hyperammonaemia then start dialysis rate at 50ml/kg/hr and titrate rate according to ammonia level. If patient has a high sodium then you can slow down the flow rates. Increasing the patient's blood pump speed will also increase the amount of citrate being delivered to the circuit.

Calculation of Prismocitrate 18/0 rate

(note the Prismax machine will calculate this rate, however it can also be manually calculated as follows)

If 4mmol/L citrate is required using Prismocitrate 18/0 that contains 18mmol citrate/1000ml: -

Use Blood flow rate (ml/min) and multiply by 60 to get rate per hour.

e.g. Blood flow rate 30ml/min

Blood flow rate 30ml/min x 60 = 1800ml/hr

To calculate volume of Prismocitrate 18/0 (Pre blood pump PBP)

(4mmol/L / 18mmol/L) x 1800ml = 400ml which will be run at 400ml/hr (PBP)

To increase clearance move patient up weight brackets
To decrease clearance move patient down weight brackets

Commented [WB1]: This table is different to the Nottingham one?

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Decrease Clearance

Weight	BFR	Dialysate	Replacement	Estimated Effluent dose
80	200	1600	200	54
70	200	1400	200	59
60	180	1200	200	61
50	150	1000	150	61
45	135	900	150	61
40	120	800	150	62
35	105	700	150	62
30	90	600	100	61
25	75	500	100	62
20	60	400	100	63
18	55	360	50	61
16	55	320	50	67
14	55	280	50	73
12	55	240	50	82
11	55	220	50	88
10	30	200	30	61
9	30	180	30	66
8	30	160	30	71
7	30	140	30	79
6	30	120	30	88
5	30	100	30	102
4	20	80	20	88
3	20	60	20	111
2	20	40	20	157

Increase Clearance

11 Patient fluid removal rate

This is calculated on an hourly basis depending on actual patient fluid balance, desired fluid balance and condition and stability of the patient. Individual prescription depends on input (i.e. nutrition, IV fluids, drugs) and output (i.e. urine, gastric, drain losses). The PrisMax will continue to run at the set hourly rate until changed by staff. The rate **must** be reviewed every hour. Beware of removing fluid too quickly.

If a negative balance is required this needs to be prescribed in ml/hr. Net fluid removal rate refers to desired net removal (e.g. 0ml/hr would mean a neutral balance to the patient, 10ml/hr would mean -10ml/hr to the patient). Net fluid removal rate and hourly actual fluid balance both need to be added together to work out patient fluid removal rate to be programmed (e.g. if total hourly input amount of IV fluids and infusions is 45ml/hr and 10ml/hr net removal is prescribed = 55mls/hr needs to be programmed into the machine). Do not remove fluid bolus given to support blood pressure or intravascular loss. Blood

products which have **not** been administered for volume should be added to the programed fluid removal rate and removed over the duration of the transfusion.

If the machine shows a minus number that means that it has gained that amount of fluid. This may occur when treatment is first commenced, but should readjust itself after a few minutes.

Deciding exactly how much fluid to remove from the patient is complex as it depends on many clinical factors including urine output, insensible loss, hypervolaemia/hypovolaemia and clinical observations.

EXTREME CAUTION should be used when setting the patient fluid loss rate, as the PrisMax will try to remove that fluid; it has no way of assessing the effect on the patient. It will continue to remove fluid even when the patient is **HYPOVOLAEMIC.** In low body weight children extra caution is advised in assessing and programming fluid removal rates. No Paediatric CRRT equipment is accurate ml for ml and there may be some discrepancies in what the machine actually achieves.

Always treat the patient NOT the machine.

12 Considerations during therapy

12.1 Care and clinical monitoring of the patient

- Continuous monitoring of cardiovascular and respiratory parameters should be undertaken.
- Ensure cardiovascular observations are recorded on PICU chart hourly or half hourly depending on stability of patient.
- All patients who are receiving CVVH/CVVHDF should have central/peripheral temperature*, heart rate and arterial blood pressure (*central temperature does not have to be a rectal temperature).
- Fluid balance needs careful monitoring because of the large volumes of fluid being removed/infused. Weigh patient on daily basis if possible
- There are inherent errors in all the measures of fluid balance therefore it is wise to assess the following factors before deciding upon the hydration status of the patient in relation to CRRT:
    - Fluid balance
    - Clinical examination (HR,ABP,CVP,CRT etc..)
    - Biochemistry
    - Haematocrit
    - Weight (preferably use a bed with weighing scales inbuilt)

Always treat the patient NOT the machine.

12.2 Pharmacological considerations

Drug removal by haemofiltration/haemodiafiltration depends on molecular weight, albumin binding, water solubility and volume of distribution, therefore some drugs' handling properties are changed by the therapy. Filtration will remove non-protein bound, water soluble drugs, which are available in the circulation. Adding dialysate flow will cause more efficient drug removal by diffusion. Drug dose changes should be checked with a pharmacist.
*Contrast is efficiently removed by filtration
*IVIG does not pass through the haemofilter most commonly used on PICU

12.3 Temperature control

As the patient's blood is removed from their body and pumped through the circuit it significantly cools down so it is essential that a blood warming device is used during treatment. There are two options to heat the patient's blood: the TherMax for ST circuits and the Prismacomfort (Barkey) for HF20 circuits. There will be on screen instructions when setting up PrisMax which will guide you through set up of both devices

- The Prismacomfort should be set 1-2^{o}C above the desired patient temperature and attached to the 'Return' line.
- As the heater sleeve covers the 'Return' line it is essential that a portion of the line is left exposed next to the patient's catheter so any air will be visible.
- The TherMax should be set at 37^{o}C
- Additional warming devices may be required (e.g. overhead heater, Bair hugger).
- Beware of both blood warming devices masking pyrexia.

13 Considerations for septic patients

13.1 Calcium infusion

Occasionally septic patients on PICU will already be on a calcium infusion due to their inotropic requirements. If this is the case, still continue to run this infusion whilst treatment via the PrisMax is commenced. Once the patient's iCa is within normal range then the calcium infusion being delivered via the Bbraun syringe pump can be turned off. The calcium infusion being delivered via the Prismaflex can be used to maintain optimum patient iCa levels.

Please be aware that if the PrisMax is discontinued for any reason then the patient won't be receiving any calcium. If treatment is going to be stopped for a while and patient is requiring a lot of inotropic support then please recommence a calcium infusion on the BBraun syringe pump as soon as possible to prevent a decrease in the patient's iCa.
This is only applicable if patient was on a calcium infusion for inotropic support pre CVVHDF.

13.2 Transmembrane Pressure (TMP)

TMP is the hydrostatic pressure gradient across the filter membrane i.e. the difference in pressure between the blood compartment and the dialysate compartment. This is the driving force that causes ultrafiltration. A rise in TMP suggests that there is clogging occurring in the filter. This is a natural occurrence during treatment and can occur more frequently in septic patients, thought to be due to the adsorption of inflammatory markers to the filter membrane. Unfortunately once the TMP starts to rise there isn't much that can be done to resolve the issue. Making the Prismaflex/ Prismax work less by reducing the patient fluid removal or replacement rate may stop TMP rising too quickly but this will mean treatment is less effective. So ultimately the only solution is to effectively stop treatment and set up a new circuit.

13.3 High flow replacement

When using heparin for anticoagulation it is possible to increase the flow rates to achieve a more efficient treatment. However this is more complicated with citrate anticoagulation, mainly due to not being able to manually change the pre blood pump flow rate. If a more efficient treatment is required then this can be achieved by moving the patient up the weight brackets until desired treatment is achieved (see Section 9 and tables attached to each Prismaflex/ Prismax). When doing this change blood pump, dialysate and replacements flow rates simultaneously.

14 Monitoring

14.1 iCa – post filter and patient

Within the first hour after treatment has been commenced, the iCa level of the filter and the patient need to be checked. Take a post filter blood sample from the blue port on the circuit and another blood sample from the patient's arterial line (systemic sample). Compare the results to the table below and alter the citrate dose and/or calcium compensation accordingly. After initial blood samples repeat both again 1 hour later even if first results in the normal range. If the second set of levels remain in the normal range then you can monitor 4 hourly.

Patients >1 year and with normal liver function:

	Filter Ca^{2+} <0.25	**Filter Ca^{2+} 0.25-0.35**	**Filter Ca^{2+} >0.35**
Patient Ca^{2+} <1.0	Decrease citrate dose by 0.5mmol/L blood	Increase calcium compensation by 10%	Increase citrate dose by 0.5mmol/L blood Increase calcium compensation by 10%
Patient Ca^{2+} 1.0-1.2	Decrease citrate dose by 0.5mmol/L blood	**Normal Ideal Values - no change needed.**	Increase citrate dose by 0.5mmol/L blood
Patient Ca^{2+} >1.3	Decrease calcium compensation by 10% Decrease citrate dose by 0.5mmol/L blood	Decrease calcium compensation by 10%	Decrease calcium compensation by 10%

Patients with liver impairment / failure, <1 year age or mitochondrial disorders:

	Filter Ca^{2+} <0.4	**Filter Ca^{2+} 0.4-0.45**	**Filter Ca^{2+} >0.45**
Patient Ca^{2+} <1.0	Decrease citrate dose by 0.5mmol/L blood	Increase calcium compensation by 10%	Increase citrate dose by 0.5mmol/L blood Increase calcium compensation by 10%
Patient Ca^{2+} 1.0-1.2	Decrease citrate dose by 0.5mmol/L blood	**Normal Ideal Values - no change needed.**	Increase citrate dose by 0.5mmol/L blood
Patient Ca^{2+} >1.3	Decrease calcium compensation by 10% Decrease citrate dose by 0.5mmol/L blood	Decrease calcium compensation by 10%	Decrease calcium compensation by 10%

- Changes must be documented and checked by two nurses and signed for on Epic MAR
- After adjustments to citrate dose and calcium compensation are made, iCa must be checked in both the patient and the filter after 1 hour.

- Check post filter and patient iCa hourly until ideal values have been established and no changes have been made for two consecutive hours, then 4 hourly.
- Frequent increased requirements for calcium compensation could indicate citrate accumulation, so check *Total Calcium/iCa patient ratio (see 13.2 below).*
- If the citrate dose is reduced, pre blood pump and total effluent will reduce. If total effluent falls below 30ml/kg/hr, gradually increase replacement flow rate until a dose of 30ml/kg/hr is achieved.

14.2 Total Calcium / iCa patient ratio (calcium T:I ratio)

Perform blood total calcium 6 hours after treatment has been commenced and take a blood gas at the same time. Divide patient's total calcium (from lab sample) by the patient's iCa (from blood gas) and then action as below. If stable repeat every 6 hours, or more frequently if clinically indicated. Inform Consultant if ratio >2.5.

Calcium T:I ratio	Action
<2.5	No change needed. Check 6 hourly
>2.5	Aim for post filter iCa 0.35-0.4mmol/L (or 0.45-0.5 if using liver impairment/failure arm algorithm) by decreasing citrate dose in 0.5mmol/L increments every 30minutes until range achieved, check calcium T:I ratio after 1 hour See *Citrate Accumulation* section if calcium T:I ratio still >2.5 after 1 hour

14.3 What bloods to take and when

Calcium monitoring – timing summary	Initially	And then
Post filter ionised Ca (blood gas from ***blue*** port in circuit Target 0.25-0.35mmol/L	Within the first hour after commencing then 1 hour after initial test	4 hourly once stable (for two consecutive hours)
Patient systemic iCa (blood gas from patient) Target 1.0-1.2mmol/L		
Post filter gas and patient gas must be taken at the same time		
Patient total calcium (not corrected calcium) Target 2.2-2.5mmol/L	6 hours after commencing	6 hourly once stable (more frequently if concerned about citrate accumulation)
Calcium ratio (total Ca/patient systemic iCa) Target ratio <2.5		
	If you are increasing calcium compensation frequently and patient systemic iCa is not improving, send a total calcium urgently and calculate a T:I ratio to check for Citrate Accumulation. Discuss with consultant.	
Blood sampling and frequency		
Arterial blood gas Pay particular attention to pH, lactate, bicarbonate, sodium, potassium, glucose, iCa	Within the first hour after commencing then 1 hour after initial test	4 hourly once stable
U's & E's, plus magnesium and phosphate	6 hours after commencing	6 hourly once stable
Clotting	Every 12 hours	
FBC	Daily	

14.4 pH acid/base balance

Aim for pH 7.35-7.45

Metabolic acidosis (pH <7.35, BE <4mmol/L, HCO_3 <22mmol/L)
Most patients with AKI have some degree of metabolic acidosis on commencement of treatment. This should improve over the first few hours of treatment. If there is a failure to improve BE/HCO_3 towards normal, consider:

- Decreasing dialysate rate by 50% from baseline, therefore more citrate will reach the patient
- Increasing blood flow rate which will increase citrate delivery
- Giving systemic sodium bicarbonate to the patient (consider respiratory acidosis contribution in first instance, so ventilation is optimised)

These will have different effects on clearance, potential for citrate toxicity and cardiovascular status and should be discussed with consultant.
If the patient has developed metabolic acidosis and high lactate alongside a persistently low iCa which is not improving despite increasing calcium concentration, then citrate toxicity should be suspected. Send a T:I ratio urgently and refer to section 14.4

Metabolic alkalosis (pH >7.45, BE >+4mmol/L, HCO3 >25mmol/L)
Please ensure other causes for metabolic acidosis have been considered and optimise these (i.e ventilation)
This can occur due to the metabolism of citrate into bicarbonate (1mmol citrate converts to 3mmol bicarbonate), plus the addition of bicarbonate via the dialysate fluid. May also indicate citrate accumulation/Net overload so check calcium T:I ratio. Consider:

- Doubling baseline dialysate flow, this will increase citrate clearance
- Decreasing blood flow (min 20mL/min) which will reduce citrate intake
- Be aware of other reasons for the alkalosis and gain ensure ventilation is optimised

These options will have differing effects on clearance, potential for citrate toxicity and cardiovascular status and should be discussed with the Consultant.

15 Potential problems whilst undergoing treatment

15.1 Emergency disconnection

In some circumstances emergency disconnection is required such as when lines have clotted, technical failure or evacuation of the unit. In these circumstances wash back should be considered if possible. CVVH/CVVHDF catheter should then be flushed with sodium chloride 0.9% and locked with heparin.

If recurrent filters are clotting despite apparent optimal anticoagulation, the addition of Epoprostenol is sometimes used to reduce platelet aggregation (although typically more common with Heparin anticoagulation). The pH of Epoprostenol is not compatible with citrate anticoagulation so would need to run in a separate line directly to patient and so may be considered after explicit discussion with the consultant on call.

15.2 Cardiac arrest

In the event of cardiac arrest while the patient is undergoing CVVH/CVVHDF, treatment should be stopped and the line aspirated, flushed and locked as time allows. It may be an option to wash back the blood in the circuit to the patient, if deemed necessary. In some circumstances continuing filtration may be appropriate (e.g. if being used for life threatening electrolyte disturbance like Hyperkalaemia). Haemofiltration catheters are central venous access and can be used instead of standard central lines in an emergency.

15.3 Air Embolism

In the event of the patient having an air embolism, attempt to aspirate air using the central line. To do so, put the patient on their left side with their head down. Summon emergency assistance.

15.4 Citrate accumulation

When more citrate is being infused than can be cleared by either metabolic or dialysis pathways, the calcium-citrate complex remains in the patient's circulation. As most of this complex is metabolised by the liver, citrate accumulation is more likely to occur in patients with liver impairment/failure. The citrate molecule itself is not toxic however the aim is to avoid the secondary effects which are hypocalcaemia and metabolic acidosis.

The main indicator for citrate accumulation is an increasing total calcium with decreasing patient iCa and a calcium T:I ratio of >2.5. If you are increasing the calcium compensation each hour because of low patient iCa consider: Could this be Citrate Accumulation?

As per section 13.2 Total Calcium/iCa patient ratio (calcium T:I ratio):

- If the ratio is high, aim for post filter iCa 0.35-0.4mmol/L (or 0.45-0.5mmol/L if using liver impairment/failure arm of algorithm) by decreasing citrate dose in 0.5mmol/L increments every 30 minutes until range achieved, check calcium T:I ratio after 1 hour.
- You can also consider decreasing blood pump speed (min 20mls/min), this will also decrease the total administered citrate.
- Discuss with PICU consultant.

If the T:I ratio calculated after 1 hour still remains high, consider the following actions to resolve the problem:

- Stop Citrate dose by reducing rate to 0mmol/L and quadruple the baseline dialysate flow (or increase to maxiumum dialysate flow rate possible for set), this will increase the citrate clearance
- Increase blood flow rate, this will prevent clotting in the circuit whilst there is no anticoagulant running.
- Send a total calcium urgently after 1 hour and repeat ratio (if result does not come back within an hour contact the laboratory and chase result)

If improvement seen:

- Restart citrate at 50% of previous citrate dose, monitor patient calcium and T:I ratio closely

- Monitor the iCa of the circuit hourly to ensure adequate anticoagulation of the circuit, aim for a new target of 0.4-0.45mmol/L (see 'Liver impairment' section of *iCa Filter and Patient Algorithm* in section 13.1 for suggested ranges)

If despite these actions the calcium T:I ratio remains high do not restart citrate and discuss converting to alternative anticoagulation with consultant.

16 Monitoring compliance with and the effectiveness of this document

Internal audit will be undertaken every 12 months to review any deviation to guideline and to monitor effectiveness of using citrate anticoagulation.

Audit results will be discussed at local PICU clinical governance meeting

17 References

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www.baxterhealthcare.co.uk
www.pcrrt.com

18 Associated documents

List supporting documents to be read in conjunction with this document, eg:

- developing Trust documents policy

Equality and diversity statement

This document complies with the Cambridge University Hospitals NHS Foundation Trust service equality and diversity statement.

Disclaimer

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Document management

The table below will be completed by the Trust documents team:

Paediatric Critical Care

Division E

Approved by:	PICU Governance meeting		
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JDTC approval date:			
Owning department:	PICU Children's services		
Author(s):	Dr Riaz Kayani, Rachael Banda		
Pharmacist:	Nigel Gooding		
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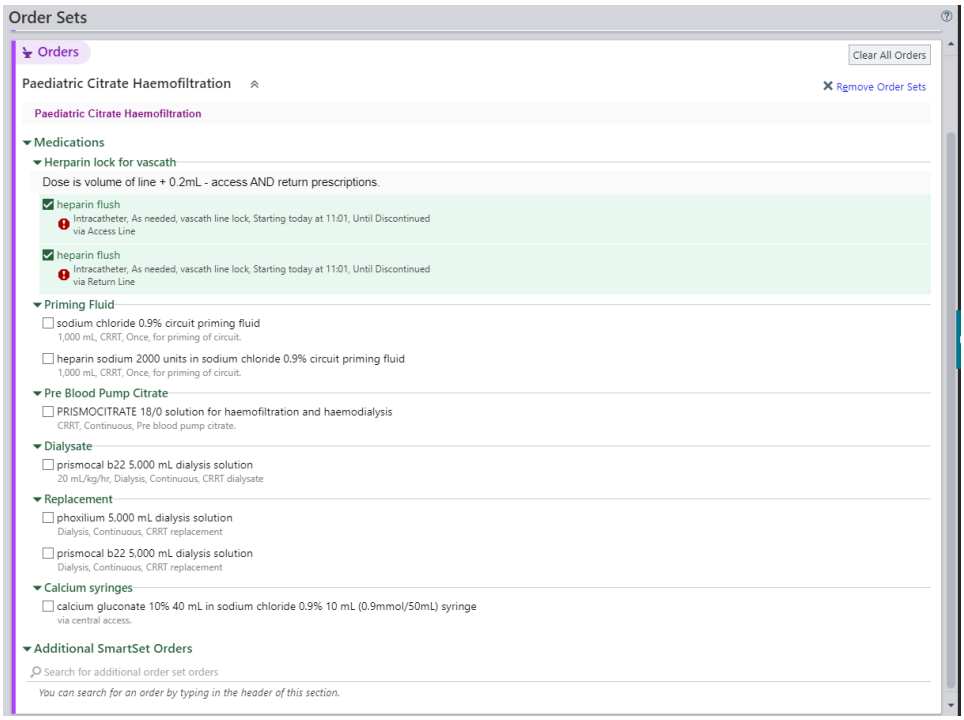
Supersedes:	Use of Continuous Ven-Venous Haemofiltration (CVVH) and Continuous Veno-Venous Haemodiafiltration (CVVHDF) within Paediatric Intensive Care Unit (PICU) Version 1		
Version number:	2		
Local reference:		Document ID:	

Appendix 1 : Use of Epic to prescribe filtration medicines / fluids

The Epic order set 'Paediatric Citrate Haemofilration' should be used to prescribe the required medicines (screenshot below)



Prismocitrate Epic prescription

Prismocitrate infusion rate, depending on whether 3mmol/L or 4mmol/L citrate is used, can be calculated as follows (as per section 9 of guideline): -

e.g. If 4mmol/L citrate is required using Prismocitrate 18/0 that contains 18mmol citrate/1000ml: -

Use Blood flow rate (ml/min) and multiply by 60 to get rate per hour.

e.g. Blood flow rate 30ml/min

Blood flow rate 30ml/min x 60 = 1800ml/hr

To calculate volume of Prismocitrate 18/0 (Pre blood pump PBP)

4mmol/L / 18mmol/L) x 1800ml = 400ml which will be run at 400ml/hr (PBP)

Calcium gluconate syringe Epic prescription

In Epic a flow rate of 0 – 40 ml/hr should be set for the calcium gluconate infusion, as the actual flow rate being administered will be calculated by the Prismaflex / Prismax software – nursing staff should document on the Epic MAR the flow rate of calcium being administered.

Appendix 2 : Quick summary guide to Citrate haemofiltration

Prescribing guidance

Mode of therapy

As with heparin anticoagulation CVVHDF should always be selected when setting up the Prismaflex. On PICU all children who require filtration with citrate anticoagulation will have CVVHDF as their chosen therapy.

Running dialysate with citrate anticoagulation has some additional benefits, such as off-loading citrate into the effluent bag which can help prevent citrate accumulation and reducing high bicarbonate levels in the patient's blood.

Flow rates

Initial Treatment Settings						
	<5kg	**5-11kg**	**11-18kg**	**18-30kg**	**30-50kg**	**>50kg**
Blood flow rate	20ml/min	30ml/min	55ml/min	3ml/kg/min		
Pre blood pump citrate	Starting dose: 4mmol/L Adjust during treatment according to algorithm (in liver impairment or <1yr, start at 3mmol/L and monitor systemic iCa closely)					
Dialysate	Commence at 20ml/kg/hr (can increase to 50ml/kg/hr)					
Replacement	20ml/hr	30ml/hr	50ml/hr	100ml/hr	150ml/hr	200ml/hr
Calcium syringe	Initially start at 100% if patient calcium normal. Adjust during treatment according to algorithm.					
Set patient gain/loss limit	This is set at 10ml/kg over 3 hours, once set this limit cannot be changed during treatment.					

Commented [SS(3]: Should this be mmol

Blood flow rate is affected by vascular access and the patient's condition.
Compared to heparin anticoagulation the initial flow rates are a lot slower: 20-55ml/min for <18kg and 3ml/kg/min for >18kg

Blood flow rates can be increased if necessary but it is important to remember that if the blood flow rate is increased the PBP citrate rate will also be increased. Speak to consultant or paediatric renal critical care nurse before changing rates.
The synchronization of the blood flow rate and PBP citrate flow rate is necessary to maintain the citrate dose at the desired level.

Citrate dose

Citrate solution is delivered to the patient's blood pre-filter, on the pre-blood pump (PBP) scale; this ensures that both the filter and circuit are anti-coagulated. The concentration of citrate added to the patient's blood before entering the filter depends on the blood flow rate and citrate infusion (PBP) flow rate.

The amount of citrate is expressed, as citrate dose, in mmol/L blood. On PICU the usual starting citrate dose will be 4mmol/L. A filter iCa concentration of 0.25-0.35mmol/L is required for optimum anticoagulation of the circuit for patients with normal liver function. Citrate dose is altered as per the algorithm in section 9 of the guideline.

Clearance

To increase clearance:

- Move the patient up to the next weight bracket (see guideline for weight brackets)

If treatment is too efficient:

- Move the patient down weight brackets to slow clearance

Decrease Clearance ↓

Weight	BFR	Dialysate	Replacement	Estimated Effluent dose
80	200	1600	200	54
70	200	1400	200	59
60	180	1200	200	61
50	150	1000	150	61
45	135	900	150	61
40	120	800	150	62
35	105	700	150	62
30	90	600	100	61
25	75	500	100	62
20	60	400	100	63
18	55	360	50	61
16	55	320	50	67
14	55	280	50	73
12	55	240	50	82
11	55	220	50	88
10	30	200	30	61
9	30	180	30	66
8	30	160	30	71
7	30	140	30	79
6	30	120	30	88
5	30	100	30	102
4	20	80	20	88
3	20	60	20	111
2	20	40	20	157

↑ Increase Clearance

Patient fluid removal

- For first hour filter is running ensure 'Patient fluid removal' rate is set at 0ml/h
- For next hour aim for a neutral patient balance e.g. if patient has 50ml/h of input then set Prismaflex 'Patient fluid removal' rate at 50ml/h
- If aim of treatment is to remove fluid from patient (net fluid removal) then this amount needs to added to the current set 'Patient fluid removal' rate

  For example:

Hourly patient input (all IV and enteral) (ml/hr)	**Hourly net patient fluid removal** (ml/hr)	**Prismaflex patient fluid removal** (ml/hr)
50	20	70

- Ensure patients fluid balance and clinical status is assessed hourly and patient fluid removal rates changed accordingly
- If patient is passing urine or has any other large output then discuss fluid removal plan with consultant

Biochemistry monitoring

Calcium monitoring – timing summary	**Initially**	**And then**
Post filter iCa (blood gas from **blue** port in circuit Target 0.25-0.35mmol/L (if normal liver function)	Within the first hour after commencing then 1 hour after initial levels	4 hourly once stable (for 2 consecutive hours)
Patient systemic iCa (blood gas from patient) Target 1.0-1.2mmol/L		
Post filter gas and patient gas must be taken at the same time		
Patient total calcium (**not** corrected/adjusted calcium) Target 2.2 - 2.5mmol/L	6 hours after commencing	6 hourly once stable (more frequently if concerned about citrate accumulation)
Calcium ratio (total Ca divided by patient systemic iCa) Target ratio <2.5	***If you are increasing calcium compensation frequently and patient systemic iCa is not improving, send a total calcium urgently and calculate a T:I ratio to check for Citrate Accumulation. Discuss with consultant.***	
Blood sampling and frequency		
Arterial blood gas Pay particular attention to pH, lactate, bicarbonate, sodium, potassium, glucose and iCa	Within the first hour after commencing then 1 hour after initial levels	4 hourly once stable
U's & E's Including calcium, magnesium and phosphate	6 hours after commencing	6 hourly once stable
Clotting	Every 12 hours	
FBC	Daily	

iCa – post filter and patient (algorithm for patients > 1yr and with normal liver function)

	Filter Ca^{2+} <0.25	**Filter Ca^{2+} 0.25-0.35**	**Filter Ca^{2+} >0.35**
Patient Ca^{2+} <1.0	Decrease citrate dose by 0.5mmol/L blood	Increase calcium compensation by 10%	Increase citrate dose by 0.5mmol/L blood Increase calcium compensation by 10%
Patient Ca^{2+} 1.0-1.2	Decrease citrate dose by 0.5mmol/L blood	**Normal Ideal Values - no change needed.**	Increase citrate dose by 0.5mmol/L blood
Patient Ca^{2+} >1.3	Decrease calcium compensation by 10% Decrease citrate dose by 0.5mmol/L blood	Decrease calcium compensation by 10%	Decrease calcium compensation by 10%

iCa – post filter and patient (algorithm for patients < 1yr and with abnormal liver function)

	Filter Ca^{2+} <0.4	**Filter Ca^{2+} 0.4-0.45**	**Filter Ca^{2+} >0.45**
Patient Ca^{2+} <1.0	Decrease citrate dose by 0.5mmol/L blood	Increase calcium compensation by 10%	Increase citrate dose by 0.5mmol/L blood Increase calcium compensation by 10%
Patient Ca^{2+} 1.0-1.2	Decrease citrate dose by 0.5mmol/L blood	**Normal Ideal Values - no change needed.**	Increase citrate dose by 0.5mmol/L blood
Patient Ca^{2+} >1.3	Decrease calcium compensation by 10% Decrease citrate dose by 0.5mmol/L blood	Decrease calcium compensation by 10%	Decrease calcium compensation by 10%

Appendix 3 :Use of haemofiltration with heparin anticoagulation

In the rare event that citrate is contraindicated for a patient e.g. in citrate accumulation, heparin can still be used for anticoagulation of the circuit.

Properties

Heparin inhibits coagulation by preventing the conversion of prothrombin to thrombin and fibrinogen to fibrin. Heparin displays almost immediate action following intravenous administration. The clotting time then returns to normal within 2-6 hours after the infusion is discontinued. It binds extensively to plasma proteins and is activated in the liver and excreted in the urine.

The action of heparin can be reversed with Protamine Sulphate. The dose is dependent on the heparin rate - see the BNFC for more information. The protamine dose should be based on the cumulative heparin dose given over the previous 2 hours.

Administration and dosage

Heparin is administered into the dedicated heparin infusion line on the access side of the Prismaflex circuit.

The initial bolus (if appropriate) should be given as blood reaches the pre filter port; this is then followed by a continuous infusion. Ensure you check patients clotting before giving a heparin bolus. The aim is to raise the patient's clotting time sufficiently to prevent clotting in the filter and lines, while not increasing the risk of bleeding to the patient.

The heparin should now be made up at the same concentration (100units/kg in 40mls) using a 50ml syringe.

Always have an APTR prior to connection to the patient, this ideally should be taken from a non-heparinised access; Ideally NOT arterial line

Once the patient is attached to the filter, sampling for anticoagulation needs to be from the first **RED PORT** on the access line, just before the heparin infusion reaches the circuit. This is to prevent risk of heparin contamination, which can occur when using arterial line or return line (blue port).

- Initial priming of circuit is with 2000units heparin in 1000mls 0.9% Sodium Chloride
- Concentration of heparin in syringe is 100units/kg in 40mls this will need to be drawn up in a 50ml syringe and infused via the infusion line in the circuit pre-filter
- Some patients may require a bolus of heparin (50units/kg) which should be administered before the patients blood reaches the membrane
- Standard initial infusion rates are; 10-30 units/kg/hr. As the filter ages the heparin dose required to reach the desired APTR increases. Usual starting dose is 20units/kg/hr.

In general the heparin infusion needs to be titrated to achieve a moderate increase in the patients APTR.
APTR target - 2.0-2.5

If the child has severe coagulopathy, active bleeding or deranged liver function consider and discuss with consultant and nurse in charge;

- not giving the initial 50units/kg bolus of heparin
- heparin free haemofiltration
- Reducing desired APTR to 1.5-2.0

HEPARINISATION - APTR

APTR	**Action**
<1.6	Discuss with consultant and NIC about giving 50unit/kg heparin bolus and increase rate by 5units/kg/hr
1.6-1.9	Increase rate by 5units/kg/hr
2.0-2.5	Continue heparin at present rate
2.5-3.0	Decrease rate by 5units/kg/hr
>3.0	STOP heparin infusion and recheck APTR in 2 hours

Check APTR within 2 hours of commencing filtration, repeat 4 hourly if APTR stable and 2 hours after any intervention.

Contraindications

- Active bleeding
- Imminent or recent surgery
- Coagulopathies such as thrombocytopenia, especially in septic and oncology patients
- Heparin Induced Thrombocytopenia (H.I.T)
- Disseminated Intravascular Coagulation (D.I.C)
- Liver disease
- Haemophilia
- Diabetes
- Pericarditis

Flow rates for heparin

Blood Flow Rates Affected by vascular access and patient's condition
Standard blood flow rate = 6-9ml/kg/min, 12-15ml/kg/min in low weight babies Minimum flow rate 30ml/min Blood flow rates will not affect clearances There is no such thing as too much blood flow (other than max limit set by filter size). In patients >30kg aim for a blood pump speed of 180-240mL/min, rates above this are not always achievable or necessary. Blood flows should be adjusted in high flow CRRT to compensate for excessive haemoconcentration of the filter

Replacement rate = ultrafiltration & convection medium and large molecule clearance (e.g. products of inflammation/cytokines)
Standard replacement rate = 30ml/kg/hr On Prismaflex this is programmed as 10ml/kg/hr for Pre Blood Pump and 20ml/kg/hr for Replacement Higher rates can be used in sepsis and hyperammonia up to 100ml/kg/hr (this should be increased incrementally and patient response closely monitored) Increasing % pre-dilution may be required when having problems with the filter. Majority pre- dilution may be needed in certain patients (**Max 90% pre, 10% post.**)

Dialysate rates = diffusion Small molecule clearance (e.g. urea/ammonia)
Standard dialysate rates = 20ml/kg/hr can be increased up to 50ml/kg/hr (this should be increased incrementally and patient response closely monitored)

In AKI no evidence exists to support one mode over another. A combination of convection and diffusion to optimise the removal of small and medium sized molecules may be preferred
Typical starting prescription for fluid overload, oliguria would be 30ml/kg/hr convection (replacement), with the addition in SIRS/Sepsis of 20ml/kg/hr diffusion (dialysis).

For heparin anticoagulation, the fluid bags will either be Prismasol 4 (if patient's potassium <6mmol/L) or Hemosol BO (if patient's potassium >6mmol/L)

Prismasol 4 (all values in mmol/L)									
Sodium	Potassium	Calcium	Magnesium	Chloride	Phosphate	Lactate	Bicarbonate	Glucose	Citrate
140	4	1.75	0.5	113.5	0	3	32	6.1	0

Hemosol BO (all values in mmol/L)									
Sodium	Potassium	Calcium	Magnesium	Chloride	Phosphate	Lactate	Bicarbonate	Glucose	Citrate
140	0	1.75	0.5	109.5	0	3	32	0	0

Adding electrolytes to replacement and dialysate fluid for filter fluids used with heparin anticoagulation

Additives are always prescribed to be added per litre of fluid and as a total dose. Care needs to be taken when making up the fluid as a result. When additives are required more frequent blood sampling will be required.

Electrolyte	Indication	Additive
Phosphate	Serum Phosphate <2mmol/L	Sodium glycerophosphate 1mmol/L (5mmols added to 5 litre bag)
Glucose	Serum glucose <6mmol/L	Glucose 1.1 grams/L (6mmol/L) (5.5 grams glucose to 5 litre bag of Hemosol BO,11mls of 50% glucose).

Management of hypernatraemia on CRRT

In cases of hypernatraemia in patients requiring CRRT it may be necessary to add sodium to replacement/dialysis fluids to ensure sodium correction does not occur too rapidly. The sodium content of both Prismasol 4 and Hemosol BO is 140mmol/L, so without the addition there is a significant risk the patients' serum sodium could drop too quickly. If required, sodium should be added to all three bags.

If an addition is required this must be clearly documented on the patients CVVH/CVVHDF EPIC Daily Prescription and Record Chart and the patient's serum sodium must be closely monitored. If the patient's plasma sodium is greater than 150mmol/L follow the guidance below for adding sodium:

Target Na^+ (mmol/L)	Addition to 5 litre bag (either Prismasol 4 / Hemosol BO)	
150	10mls of sodium chloride 30%	Remove same volume from replacement/dialysate bag before addition (e.g.. for target 150mmol/L remove 10mls from Prismasol 4/Hemosol BO, then add 10mls sodium chloride 30%)
155	15mls of sodium chloride 30%	
160	20mls of sodium chloride 30%	
165	25mls of sodium chloride 30%	
170	30mls of sodium chloride 30%	
175	35mls of sodium chloride 30%	
180	40mls of sodium chloride 30%	
185	45mls of sodium chloride 30%	
190	50mls of sodium chloride 30%	

NB: Sodium chloride 30% contains 5mmol/ml of sodium.

Appendix 4 : Prescription chart only for use during Epic downtime

Paediatric CVVHDF Citrate Anticoagulation Daily Prescription And Observation Chart

Please affix Patient Label Here Patient Name D. O. B NHS number	**DRUG ALLERGY or ADVERSE EFFECT** **If none known tick box** ☐		
	Medicine/other	Nature of reaction	Source
	Signature **Date** This box must be completed & signed by a prescriber or pharmacist		

Date:		**Weight:**	kg
Circuit required:			
HF20 (0-12kg)		ST60 (12-25kg)		ST100 (>25kg)	
Vascular access:			
<10kg	10-20kg	>20kg
2x 18G cannulas	8Fr x 10cm or 12.5cm	11Fr x 15cm or 20cm
6.5Fr x 7.5cm or 12.5cm 8Fr x 10cm	Other line:	
Make:		
Site:		Date inserted:	

	Print Name	**Signature**	**Date/Time**
Prescribing doctor			
Set up nurse			
Checking nurse			
If additional circuit required sign below:			
Set up nurse			
Checking nurse			
Reason for new circuit			
If additional circuit required sign below:			
Set up nurse			
Checking nurse			
Reason for new circuit			

Heparin Lock for vascath				
*Use 100units/ml heparin, line lock = volume of line + 0.2ml				
Access: ml	Return: ml	Dr sign		
Date/Time given:		Nurse sign		
Date/Time given:		Nurse sign		

Use in conjunction with the following:

~ Guideline: Use of Continuous Ven-Venous Haemofiltration (CVVH) and Continuous Veno-Venous Haemodiafiltration (CVVHDF) within Paediatric Intensive Care Unit (PICU)

Fluid prescription					
		Dr sign	Nurse set-up sign		Set-up Date/time
Priming Fluid	0.9% sodium chloride + 2000 units heparin				
	0.9% sodium chloride				
Pre Blood Pump Citrate	Prismocitrate 18/0				
Dialysate	Prism0cal B22				
Replacement	Phoxilium				
	Prism0cal B22/ Prismasol 4				
Calcium Gluconate Infusion	40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)				
Additives					
Do not add any additives to any fluid bags					

Pre Blood Pump/Replacement/Dialysate Fluid Administration Record				
Date/ time	**Fluid type**	**Scale**	**Nurse sign**	

Calcium gluconate infusion record				
Date/time		**Infusion**	**Nurse sign**	
Made up	Started			
		40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)		
		40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)		
		40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)		
		40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)		
		40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)		
		40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)		
		40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)		

		40ml calcium gluconate 10% with 10ml sodium chloride 0.9% (9mmol in 50ml)		

	Initial Treatment Settings					
	<5kg	**5-11kg**	**11-18kg**	**18-30kg**	**30-50kg**	**>50kg**
Blood flow rate	20ml/min	30ml/min	55ml/min	3ml/kg/min		
Citrate dose	Starting dose: 4mmol/L. Adjust during treatment according to algorithm. (in liver impairment or <1yr, start at 3mmol/L and monitor systemic iCa closely)					
Dialysate	Commence at 20ml/kg/hr (can increase to 50ml/kg/hr)					
Replacement	20ml/hr	30ml/hr	50ml/hr	100ml/hr	150ml/hr	200ml/hr
Set patient gain/loss limit	This is set at 10ml/kg over 3 hours, once set this limit cannot be changed during treatment.					
Calcium syringe	Initially start at 100% if patient calcium normal. Adjust during treatment according to algorithm.					
Set patient gain/loss limit	This is set at 10ml/kg over 3 hours, once set this limit cannot be changed during treatment.					

Prescribed Flow Rates					
Patient fluid loss/gain limit (ml/3hrs)	**Blood flow rate** (ml/min)	**Dialysate** (ml/hr)	**Replacement** (ml/hr)	**Dr sign**	**Nurse sign**

Anticoagulation Rates			
Citrate dose (mmol/L blood)	**Calcium compensation** (%)	**Dr sign**	**Nurse sign**

Fluid Removal Rates					
Hourly patient input (all IV and enteral) (ml/hr)	**Hourly net patient fluid removal** (ml/hr)	**Prismaflex patient fluid removal** (ml/hr)	**Overall midnight patient fluid balance target**	**Dr sign**	**Nurse sign**

Midnight Fluid Removal Review					
Hourly patient input (ml/hr)	**Hourly net patient fluid removal** (ml/hr)	**Prismaflex patient fluid removal** (ml/hr)	**Overall midday patient fluid balance target**	**Dr sign**	**Nurse sign**

Changes to initial prescription							
Date/ time	**Blood** ml/min	**Dialysate** ml/hour	**Replacement** ml/hour	**Citrate dose** mmol/L	**Calcium compensation** (%)	**Patient fluid removal**	**Sign**

Date:												
Time	**0800**	**0900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**	**1600**	**1700**	**1800**	**1900**
Citrate dose (mmol/L)												
Calcium comp. (%)												
Calcium syringe rate												
iCa Patient												
iCa filter												
Total calcium T:I ratio												
Initials												
Date:												
Time	**2000**	**2100**	**2200**	**2300**	**2400**	**0100**	**0200**	**0300**	**0400**	**0500**	**0600**	**0700**
Citrate dose (mmol/L)												
Calcium comp. (%)												
Calcium syringe rate												
iCa Patient												
iCa filter												
Total calcium T:I ratio												
Initials												

Blood results				
	Time:	**Time:**	**Time:**	**Time:**
Total calcium				
Magnesium (Correct <0.7)				
Phosphate (Correct <1.0				
Potassium				
Correction required:				

Safety checks			
	Night nurse	**Day nurse**	
Prescription reviewed			
Cross matched blood available			
Disconnection kit/Recirculation kit			
Patient fluid assessment			
Emergency drugs & fluids			
Pharmacy & stores stock levels checked including calcium gluconate			
Patient Hct checked and changed on Prismaflex		Hct:	

Addendum April 2024 – to be used until further notice

Current POC advice regarding blood gas machine usage with CVVH samples

For calcium monitoring please continue to take a post filter and patient sample concurrently as per the policy then:

- Run the post filter sample on the 500e gas machine (nurses station) DO NOT RUN ON THE 1265 IN THE SLUICE IT CANNOT ACCURATELY ANALYSE IONISED CALCIUM MEASUREMENTS THAT LOW.

- Run the patient sample on the 1265 gas machine (sluice) – POC say we can also run the patient samples on the 500e (they are concerned that if a patient develops citrate accumulation the 1265 may struggle to analyse the ionised calcium) but usually you don't get a Na value when using this gas machine.