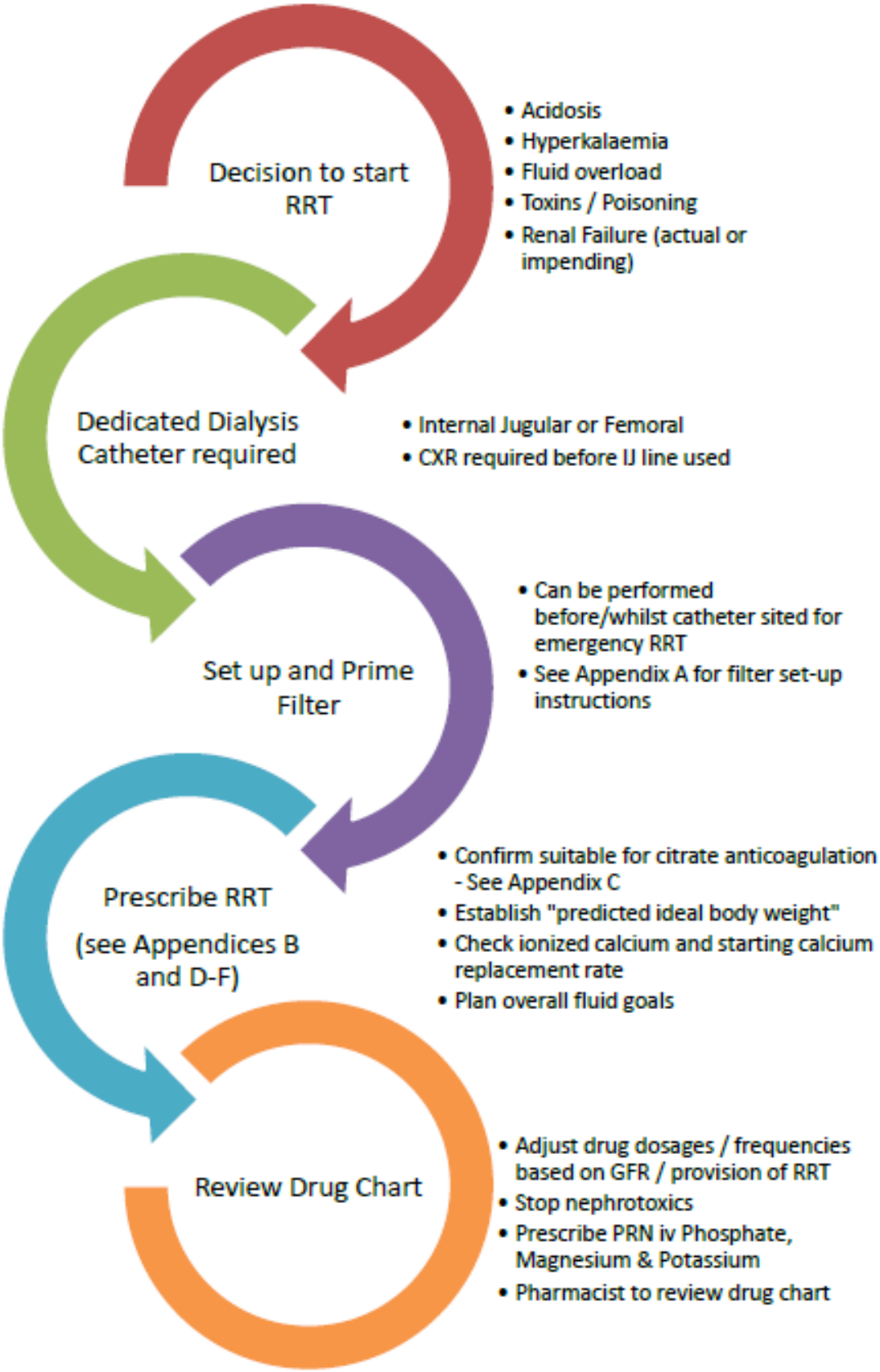

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Date : October 2016 (reviewed January 2021)

Next Review Date : January 2023

Renal Replacement Therapy Guidelines

AIM: To provide guidance on the management of patients requiring Renal Replacement Therapy
SCOPE: All adult ICUs within Royal Sussex County Hospital and Princess Royal Hospital

1. INTRODUCTION

RRT is commonly used to treat the physiological disturbances present when renal function is impaired; these include acidosis, hyperkalaemia, uraemia & fluid overload. RRT can also be used to enhance clearance of small sized, water soluble toxins / poisons / drugs.

2. PROCESS

Choice of dialysis catheter site and catheter length

Recommendation (Action)	Justification (Rationale)
For standard patients use a 15 cm line for the RIJV and 20 cm for the LIJV	Ideally, the catheter tip should sit in the distal SVC or just into the right atrium. At this point in the venous circulation, there is the greatest capacity for blood aspiration without excess negative pressure. Frequent interruptions to flow by excess negative pressure causes filter thrombosis and loss of the RRT circuit.
Use femoral lines, use the longest line available	The more proximal in the IVC, the greater the vessel diameter and better the access flow without excess negative pressure. This more than compensates for the increased resistance to flow created by the longer catheter length.

Recommendation (Action)	Justification (Rationale)
Avoid using the subclavian veins	Subclavian access is associated with development of subclavian venous stenosis. This complication significantly impairs AV fistula formation in the 5% of patients who receive RRT on the ICU and who remain dialysis dependent.

Standard RRT Prescription

Recommendation (Action)	Justification (Rationale)
RRT dose	The evidence suggests that the "dose" of RRT is less important than actually getting on and delivering it.
Type of RRT	Patients on the critical care unit receive CVVHF unless specifically directed otherwise. There is no strong evidence to demonstrate superiority of any of the different CRRT therapies.
Prescription of RRT	Only Critical Care medical staff may prescribe RRT on the ICU. Always use a BSUH RRT prescription sheet (see Appendix B). Use the RRT prescription sheet appropriate for the choice of anticoagulation - check the exclusion criteria on the "Anticoagulation choice for RTT in BSUH Critical Care" (see Appendix C).

Recommendation (Action)	Justification (Rationale)
Blood pump speed	Blood pump speed is tightly coupled to citrate infusion rate. See the tables below for precise pump speeds, exchange volumes and necessary blood flow rates.
Citrate pump speed	To achieve accurate citrate delivery into the CRRT circuit, preventing excess citrate delivery or insufficient anticoagulation, it is necessary to tightly couple the blood and citrate pump speeds. Always use the tables when setting up RCA therapy. Target post-filter ionized calcium concentration is <0.5 mmol/L. See appendix B for further details.
Aim for 25 ml/kg/hr exchange rate	Aim to deliver 20-25 ml/kg/hr of "effluent volume" (the amount of plasma water and its solutes removed by the RRT machine). The tables in Appendix D and Appendix F demonstrate the appropriate pump speed and effluent volume settings to achieve a selection of exchange rates. Patient weight is "predicted ideal body weight" = 45.4 + [0.89 x (height {cm} – 152.4)] (+4.5 if male). If the patient height is unknown, measure the patient with endotracheal tube tape, and use the wall mounted steel rulers to calculate it.

Recommendation (Action)	Justification (Rationale)
Use of higher dose therapy (35 ml/kg/hr)	There is no benefit seen in hard clinical endpoints (e.g. mortality or length of stay) when patients are routinely treated with higher dose therapy. Despite this, many critical care clinicians choose to use higher RRT doses in patients with severe acidosis, severe hyperkalaemia, septic shock, etc. Higher dose therapy may be indicated as initial therapy for the most unwell patients, with a planned reduction down to 25 ml/kg/hr after clinical stability is achieved. Higher dose therapy should only be used after agreement with the ICU Consultant.

Recommendation (Action)	Justification (Rationale)
Substitution fluids	There are two types of substitution fluid - both ACCUSOL 35 - one has 4mmol/L Potassium and the other none. Use potassium-free solutions in hyperkalaemic patients, and swap to 4mmol/L potassium bags as the serum potassium falls.

Serum Potassium (mmol/L)	**Which two bags to hang**
≥ 6 (recheck Potassium hourly)	2 x ACCUSOL 35
5 - 5.9	1 x ACCUSOL 35 1 x ACCUSOL 35 potassium 4 mmol/L
3.5 - 4.9	2 x ACCUSOL 35 potassium 4 mmol/L
< 3.5 (recheck Potassium hourly)	2 x ACCUSOL 35 potassium 4 mmol/L plus supplement with iv Potassium minibags

Recommendation (Action)	Justification (Rationale)
Set a Fluid Balance Goal	Plan an overall fluid goal for your patient for the next 12-24 hours. There's no added benefit to "removing" lots of fluid on the filter only to give it all back as fluid challenges when their Cardiac Output drops.
The use of CVVHDF	CVVHDF is slightly different to CVVHF. CVVHDF uses a flow of dialysate within the filter to add a diffusive process for clearing small solutes, in addition to the convective therapy of the filtration. CVVHDF enables higher clearances of small solutes, but uses up substantially more fluid to run the CRRT machine (and is thus more expensive). There has been no overall outcome benefit demonstrated with routine use of CVVHDF over CVVHF. When the Aquarius system performs CVVHDF, it simply runs the "pre-filter" line directly into the proximal dialysate port of the filter cartridge. Therefore you cannot have CVVHDF with any "pre-dilution" so there is an increased risk of filter clotting. On the Aquarius, citrate anticoagulation and CVVHDF are incompatible. This is because the Aquarius use the same calcium-containing substitution fluid as dialysate, and therefore the citrate effect would be cancelled out within the filter itself and the circuit would clot. Reserve CVVHDF for those patients who are likely to benefit from this therapy over conventional RRT.

Special Circumstances

Recommendation (Action)	Justification (Rationale)
Unstable patients (i.e. high vasopressor requirements) need a more careful initiation onto RRT.	The low blood pump speeds for citrate anticoagulation mitigates against this somewhat. If using alternative anticoagulation strategies, consider starting at less than 25 ml/kg/hr. See Appendix B '15' protocol. Have fluids, inotropes and vasopressors ready.
The true end-stage renal failure who needs emergent RRT having never had any before	Might have a urea over 40-50 mmol/L or more. Start gently to avoid rapid changes in biochemistry – consider 15 ml/kg/hr effluent volumes.
The patient with severe hyponatraemia	RRT will rapidly correct serum sodium, which can only be prevented by making the RRT much less efficient and/or by supplying additional free water to keep the serum sodium and osmolality down. Ideally delay the RRT until serum sodium has settled towards normal. Do not use CVVHDF in these patients.
The patient with TBI or SAH or other major brain injury	If high serum sodium is a goal of therapy, then this will be prevented by RRT unless additional hypertonic saline is administered. One option is to infuse 30% Sodium Chloride at 0.1 ml/kg/hr via CVC and monitor the serum sodium hourly, adjusting (increasing) the 30% Sodium Chloride rate to achieve target serum Sodium.
Poisoning	Only certain drugs are cleared with RRT – small solutes, water soluble. They tend to have a small-moderate volume of distribution and are minimally protein bound. If you are providing RRT solely to clear them, then consider using CVVHDF, with higher effluent volumes (35 ml/kg/hr) and expect longer treatment times.

Recommendation (Action)	Justification (Rationale)
Severe Hyperkalaemia	With life threatening hyperkalaemia, the first goal is cardioprotection with IV calcium. The second goal is potassium shift into cells with insulin/dextrose and/or beta-agonists. RRT will clear body potassium if the kidneys are unable to do this. Potassium is more effectively removed with diffusive techniques (dialysis) than convective techniques (filtration) but often the requirement for monitoring or cardiovascular support, or the availability of renal dialysis nurses, makes RRT on critical care necessary. Use CVVHDF with 35 ml/kg/hr volumes for initial therapy in *life-threatening* hyperkalaemia. Potassium will take a few hours to normalise. Swap to standard CVVHF once it has normalised. If signs of cardiac instability due to hyperkalaemia during therapy then do use further IV calcium and then insulin/dextrose as necessary. RRT can be continued during cardiac arrest if necessary, but great care must be taken to ensure that the arrest is not due to complications of the extracorporeal circuit.

Anticoagulation

Recommendation (Action)	Justification (Rationale)
Frist line choice is regional citrate anticoagulation (RCA)	RCA delivers better filter longevity with fewer bleeding complications. It is safe in patients at risk of bleeding as it delivers no systemic anticoagulation effect.
Second line choice is Unfractionated Heparin delivered directly into the CRRT circuit	Heparin is inexpensive, effective, reversible, easily titrated and ICU staff are familiar with its use and complications. See Appendix C
For patients who already have low platelets and RCA is unsuitable, use Flolan.	Epoprostenol (Flolan) at 5 nanograms/kg/min relatively protects platelets from damage through the circuit. See Appendix C
For patients with HIT who need systemic anticoagulation and RRT, use Argatroban	Argatroban is an injectable direct thrombin inhibitor with a short half-life which is suitable for patients on CRRT. See Appendix C
Review lines if recurrent clotting	It the circuit recurrently clots the most likely problem is intravascular access, not the anticoagulant
Continue routine VTE prophylaxis	Of the above options, only Argatroban delivers sufficient systemic anticoagulation to remove the need for chemical VTE prophylaxis. Please see Unit VTE guideline for further details

Drugs

Recommendation (Action)	Justification (Rationale)
Drug dosing is altered in CRRT	ICU pharmacist must review the drug chart and alteration may be required. Out of hours advice is available from the on-call Pharmacist. The BSUH prescribing App has some information on drug dosing in AKI.
Dosing needs regular review	The dosing for patients on CRRT is not always the same as the dosing for patient with low GFR. The Renal Drug Database is the standard reference source, but does not provide individualised dosing recommendations based on dialysate and blood flow rates etc. Ensure doses are individualised to the patient's needs. Please take care to adjust medications again if filter is stopped for over 12 hours.
Ensure all patients are appropriately loaded	AKI and CKD do not change the patient's volume of distribution significantly, but may affect clearance. These patients are frequently underdosed. Therefore commence an antibiotic course on full doses to achieve antimicrobial effect early, consider potential subsequent reduction in dose or frequency depending on the drug in question.
Ensure doses are calculated using ideal body weight (IBW), unless Obese	IBW (kg) = 45.4 + [0.89 x (height {cm} – 152.4)] (+4.5 if male). If obese (BMI>30) use dose determining weight: Dose determining weight (DDW) (kg) = IBW + 0.4 x (actual body weight – ideal body weight)

3. GLOSSARY

RRT Renal Replacement Therapy

CRRT Continuous Renal Replacement Therapy

CVVHF Continuous VenoVenous Haemofiltration

CVVHDF Continuous VenoVenous Haemodiafiltration

GFR Glomerular Filtration Rate

HIT Heparin Induced Thrombocytopaenia

IBW Ideal Body Weight

RCA Regional Citrate Anticoagulation

SAH Sub-Arachnoid Haemorrhage

TBI Traumatic Brain Injury

4. REFERENCES AND ONLINE RESOURES

KDIGO clinical practice guideline 2012

Meta-analysis of regional citrate vs heparin-based anticoagulation for CRRT on ICU 2015

APPENDIX A

FILTER SET UP

Setting up the Aquarius RRT machine is described in detail elsewhere, including here

APPENDIX B

BSUH RRT PRESCRIPTION SHEET

The RRT prescription sheet is available on the Level 7 Critical Care Unit, or can be found on the BSUH critical care microguide site under
Clinical Guidelines ICU >> Renal Support >>

Brighton and Sussex University Hospitals NHS Trust

Renal replacement therapy prescription chart

Name _____
DoB _____
Unit No. _____
Predicted Ideal body weight *

** For use with Regional Citrate Anticoagulation RRT only **

Please follow the RRT guideline, available on the Intranet

Date	Time	Protocol to follow (1, 2 or 3)	Blood pump speed (mL/min)	Citrate Pump Speed (mL/hr)	Substitution fluid	Fluid removal per hour OR	Overall fluid balance per 24 hrs (target)	Initial Calcium replacement rate (mL/hr)	Doctor's NAME & Signature
					Accusol-35 +/- KCl				
					Accusol-35 +/- KCl				
					Accusol-35 +/- KCl				
					Accusol-35 +/- KCl				
					Accusol-35 +/- KCl				

Each prescription is valid for 24 hours only.

For any change to the prescription a new row must be filled in, dated, timed & signed

Protocol 1, 2 or 3: See RRT guideline

Fluid Balance: Fill in only one of the grey boxes for each prescription

Calcium replacement: See RRT guideline

* Predicted Ideal Body Weight (kg) =

45.4 + [0.89 x (height {cm} – 152.4)] (+ 4.5 if male)

Brighton and Sussex University Hospitals NHS Trust

Renal replacement therapy prescription chart

Name _____
DoB _____
Unit No. _____
Predicted Ideal body weight *

** For use with Heparin, Flolan, Argatroban or Anticoagulant-free RRT only **

Please follow the RRT guideline, available on the Intranet

Date	Time	Mode (CVVH or CVVHDF)	Target exchange rate (ml/kg/hr)	Substitution fluid	Fluid removal per hour OR	Overall fluid balance per 24 hrs (target)	Anticoagulation (Heparin, Flolan, Argatroban, None)	Doctor's NAME & Signature
				Accusol-35 +/- KCl				
				Accusol-35 +/- KCl				
				Accusol-35 +/- KCl				
				Accusol-35 +/- KCl				
				Accusol-35 +/- KCl				

Each prescription is valid for 24 hours only.

For any change to the prescription a new row must be filled in, dated, timed & signed

Exchange rate: The dose of RRT should meet the patient's needs and take into account their acid-base status and degree of electrolyte derangement. For most patients, achieving 25 ml/kg/hr affords the same outcomes as achieving higher doses of RRT. See RRT guideline

Fluid Balance: Fill in only one of the grey boxes for each prescription

Anticoagulation: See guidelines in red CRRT folders & on the Intranet

* Predicted Ideal Body Weight (kg) =

45.4 + [0.89 x (height {cm} – 152.4)] (+ 4.5 if male)

APPENDIX C

ANTICOAGULATION

Frist line choice is Regional Citrate Anticoagulation.
See important contra-indications in the chart below.

Second line choice is Unfractionated Heparin delivered directly into the CRRT circuit.
The Heparin protocol for priming and for subsequent adjustment is available on the BSUH critical care microguide site under
Clinical Guidelines ICU >> Renal Support >>

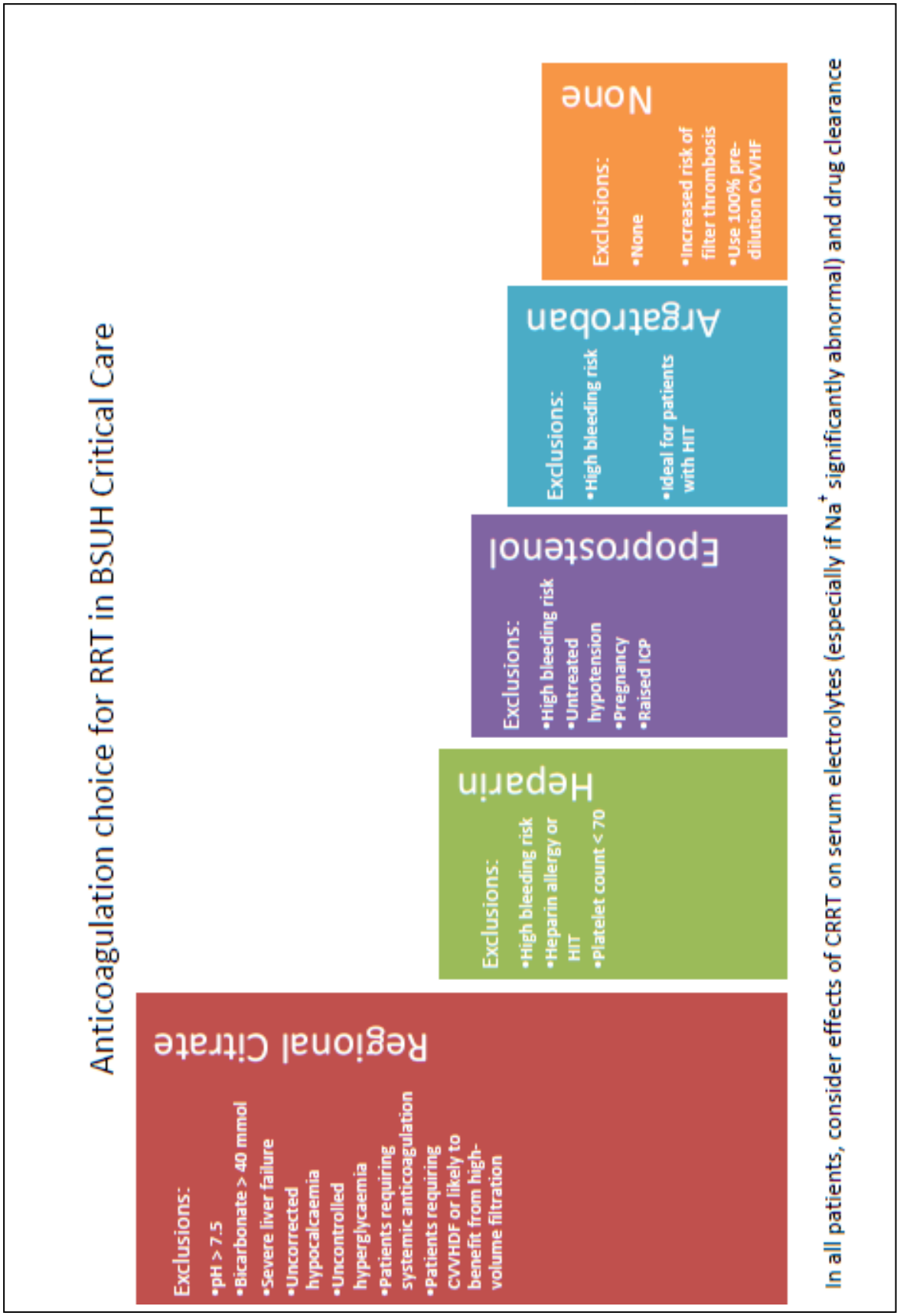
For patients who already have low platelets, use Epoprostenol (Flolan™) at 5 nanograms/kg/min.
The Epoprostenol protocol is available on the BSUH critical care microguide site under
Clinical Guidelines ICU >> Renal Support >>

For patients with HIT who need systemic anticoagulation and RRT, use Argatroban.
The Argatroban protocol is available on the BSUH Pharmacy website under
Prescribing Guidelines >> 2. Cardiovascular System >>2.3 Anticoagulants >> 2.3.1 Injectable anticoagulants >> Agratroban for HIT protocol

For patients who cannot receive any anticoagulation, use 100% pre-filter dilution, and increase to 35 ml/kg/hr exchange rates to maintain effective RRT.

If the circuit recurrently clots the most likely problem is the vascular access, not the anticoagulant.

All patients should continue to receive VTE prophylaxis whilst on RRT.
(This is usually in the form of Unfractionated Heparin 5000 units s/c TDS)


Anticoagulation choice for RRT in BSUH Critical Care
Regional Citrate
Exclusions:
•pH > 7.5
•Bicarbonate > 40 mmol
•Severe liver failure
•Uncorrected hypocalcaemia
•Uncontrolled hyperglycaemia
•Patients requiring systemic anticoagulation
•Patients requiring CVVHDF or likely to benefit from high-volume filtration
Heparin
Exclusions:
•High bleeding risk
•Heparin allergy or HIT
•Platelet count < 70
Epoprostenol
Exclusions:
•High bleeding risk
•Untreated hypotension
•Pregnancy
•Raised ICP
Argatroban
Exclusions:
•High bleeding risk
•Ideal for patients with HIT
None
Exclusions:
•None
•Increased risk of filter thrombosis
•Use 100% pre-dilution CVVHF
In all patients, consider effects of CRRT on serum electrolytes (especially if Na+ significantly abnormal) and drug clearance

APPENDIX D

PROTOCOL for REGIONAL CITRATE ANTICOAGULATION CVVHF

Protocol 1 – starting therapy for all patients

25ml/kg/hr ** Remember to use predicted ideal body weight, not total body weight **
20 % Filtration Fraction

Patient weight (kg)	Blood pump speed (mL / min)	Citrate pump speed (mL / hr)	Total exchange (mL / hr)
< 50	100	150	1200
51-60	120	180	1400
61-70	140	210	1700
71-80	160	240	1900
> 80	190	285	2300

Predicted ideal body weight =

45.4 + [0.89 x (height {cm} – 152.4)] (+4.5 if male)

If Alkalosis develops (pH > 7.5 / HCO_3^- > 40), reduce the systemic delivery of citrate by increasing filtration fraction – use Protocol 2

If the total to ionized calcium ratio is greater than 2.5, reduce the systemic delivery if citrate by increasing filtration fraction – use Protocol 2

If either complication will not resolve on Protocol 2, then discontinue RCA.

Protocol 2 – alternative therapy if alkalosis develops

25ml/kg/hr ** Remember to use predicted ideal body weight, not total body weight **
25 % Filtration Fraction

Patient weight (kg)	Blood pump speed (mL / min)	Citrate pump speed (mL / hr)	Total exchange (mL / hr)
< 50	Blood pump speed too low to safely continue with RCA for CVVHF		
51-60	100	150	1500
61-70	120	180	1800
71-80	130	195	2000
> 80	150	225	2300

Protocol 3 – higher-dose therapy for selected patients

[CONSULTANT DECISION ONLY]

35ml/kg/hr ** Remember to use predicted ideal body weight, not total body weight **
20 % Filtration Fraction

Patient weight (kg)	Blood pump speed (mL / min)	Citrate pump speed (mL / hr)	Total exchange (mL / hr)
< 50	150	225	1800
51-60	180	270	2100
61-70	200	300	2400
71-80	240	360	2800
> 80	270	405	3200

If alkalosis develops on Protocol 3 – swap to Protocol 1 in the first instance

Blood Monitoring for CRRT using Regional Citrate Anticoagulation

Pre-CVVHF with RCA

Check U&E, total calcium, magnesium (within previous 12 hours)
ACTION – if total magnesium <0.9 then administer iv replacement as usual

Check blood gas for pH, bicarbonate, ionized calcium (within previous 2 hours)
ACTION – if pH > 7.50 or bicarbonate >40 mmol then RCA contraindicated
ACTION – if ionized calcium < 0.8, DO NOT commence RCA until systemic hypocalcaemia has been corrected.
ACTION - If ionized calcium > 0.8, follow protocol for initial calcium supplementation in RCA

1 hour after starting CVVHF

Check arterial blood gas for pH, bicarbonate, ionized calcium
ACTION – follow protocol for calcium replacement and alkalosis

3 hours after starting CVVHF

Check arterial blood gas for pH, bicarbonate, ionized calcium
ACTION – follow protocol for calcium replacement and alkalosis

Every 6 hours whilst on CVVHF with RCA

Check arterial blood gas for pH, bicarbonate, ionized calcium
ACTION – follow protocol for calcium replacement and alkalosis

Every 12 hours whilst on CRRT

Check U&E, Total calcium, magnesium, phosphate
ACTION – review prescription chart and replace electrolytes if necessary
Aim [Magnesium] ≥ 1.0 whilst on CVVHF with RCA

Calculate total to ionized calcium ratio
(total calcium divided by ionized calcium; result should be less than 2.5)
ACTION – review RCA prescription – see Appendix D

APPENDIX E

PROCOTOL for CALCIUM REPLACEMENT in RCA

Calcium replacement solution is prepared with 10 mL of 10 mmol in 10 mL calcium chloride, diluted into 990 mL of 0.9% Sodium Chloride (thus resulting in a 10 mmol/L calcium chloride solution). Hang this on the SILVER scale
The Aquarius machine delivers it into return line below the drip chamber via the SILVER roller-pump.

Calcium replacement rate is guided by the systemic ionized calcium level (the calcium result from the blood gas machine) rather than the total calcium level (the result from the laboratory). Arterial or venous blood gases are suitable for assay, but do not use central venous blood if the CVC and Vascath tips are close to one another.

Please note that two versions of calcium are used in this protocol:

10% calcium chloride *mini-jets* for immediate treatment of systemic hypocalcaemia

10 mmol in10 mL calcium chloride *vials for dilution* in 990mls of 0.9% Sodium Chloride

Table 1: Calcium replacement *when commencing CVVHF with RCA*

Systemic ionized calcium result	*Initial* rate of Calcium replacement solution	Repeat monitoring (systemic ionized calcium)
< 0.80	Do not commence CVVHF with RCA until medical review and systemic hypocalcaemia has been corrected	
0.80 – 0.90	75 mL / hr	1 hour after commencing CVVHF
0.91 – 1.00	50 mL / hr	1 hour after commencing CVVHF
> 1.00	Nil Hang the “NO CALCIUM” bag	1 hour after commencing CVVHF

Table 2: Calcium replacement *when CVVHF with RCA is already running*

Systemic ionized calcium result	***Initiation and Adjustment* to rate of Calcium replacement solution**		**Repeat monitoring (systemic ionized calcium)**
	If Calcium had not yet started	If Calcium was already running	
< 0.80	Administer 5 mL of 10% calcium chloride mini-jet by slow iv bolus (via central line) immediately • Discard the "NO CALCIUM" bag • Prepare calcium replacement solution • Start infusion at 100 mL/hr	Administer 5 mL of 10% calcium chloride mini-jet by slow iv bolus (via central line) immediately • Increase rate by 50 mL/hr (max 175 mL/hr) • If infusion was already at 175 mL/hr, contact ICU consultant and swap to alternative anticoagulation for CRRT	1 hour
0.81 – 0.90	• Discard the "NO CALCIUM" bag • Prepare calcium replacement solution • Start infusion at 75 mL/hr	• Increase rate by 25 mL/hr (max 175 mL/hr) • If infusion was already at 175 mL/hr, contact ICU consultant and swap to alternative anticoagulation for CRRT	3 hours
0.91 – 1.20	No change	No change	6 hours
> 1.21	No change	• Decrease rate by 25 mL/hr • Inform doctor if ionized calcium >1.5	3 hours

APPENDIX F

STANDARD TABLES for HEPARIN, EPOPROSTENOL, ARGATROBAN and ANTICOAGULANT-FREE CVVHF or CVVHDF

Use the same tables for CVVHDF, but use the "pre-dilution" pump speeds for "dialysate" pump speeds instead

25ml/kg/hr ** Remember to use predicted ideal body weight, not total body weight **

Patient weight (kg)	Total exchange (ml/hr)	Pre-dilution (ml/hr)	Post-dilution (ml/hr)	Minimum blood pump speed (ml/min)	Filtration fraction
<50	1300	400	900	150	15%
51-60	1500	500	1000	180	14%
61-70	1800	600	1200	200	15%
71-80	2000	700	1300	220	16%
81-90	2300	900	1400	250	16%
>90	2500	1000	1500	280	15%

35 ml/kg/hr

Patient weight (kg)	Total exchange (ml/hr)	Pre-dilution (ml/hr)	Post-dilution (ml/hr)	Minimum blood pump speed (ml/min)	Filtration fraction
<50	1800	700	1100	180	10%
51-60	2100	700	1400	200	12%
61-70	2500	700	1800	220	13%
71-80	2800	900	1900	220	14%
81-90	3200	1100	2100	250	14%
>90	3500	1100	2400	280	14%

15 ml/kg/hr

Patient weight (kg)	Total exchange (ml/hr)	Pre-dilution (ml/hr)	Post-dilution (ml/hr)	Minimum blood pump speed (ml/min)	Filtration fraction
<50	800	300	500	80	15%
51-60	900	300	600	100	14%
61-70	1100	400	700	110	15%
71-80	1200	400	800	130	15%
81-90	1400	500	900	140	15%
>90	1500	500	1000	160	15%