Supporting Guidance for Renal Replacement Therapy in Intensive Care

Reference No:

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Philosophy of RRT

Renal replacement therapy (RRT) attempts to support the failing kidney through providing the following functions:

1. Fluid balance management in the oligo/anuric patient
2. Clearance and excretion of cations, nitrogenous waste and acidosis
3. Management of the complications of uraemia eg lethargy
4. Clearance of certain drugs

A useful aide memoire is A, E, I, O, U (acidosis, electrolytes, input.output (fluid), urea).
RRT can only support the excretory functions of the failing kidney and none of the endocrine or secretory functions

Choosing how and when to offer RRT

There are numerous RRT techniques. This leads to a forest of confusing acronyms. However, all share the basic aims above. Examples include continuous modalities ie running 24hours/day ('CRRT' eg CVVH, CVVHDF) to more aggressive, intermittent modalities, aiming to achieve effective renal replacement in a much shorter time period, freeing the patient from the machinery for longer periods (IHD, IHDF, SLEDD, peritoneal dialysis). Please see appendix for a fuller explanation and demonstration of these modes.

There is limited evidence available to demonstrate a clear outcome benefit to the use of continuous techniques relative to intermittent. However, there is a clear consensus that in the critically ill, CRRT offers greater haemodynamic stability and an improved 24 hour clearance profile. Intermittent techniques produce logistical difficulties in terms of the availability of trained staff and machines, traditionally provided by renal physicians and their staff. CRRT machines are 'nurse led' by ICU staff familiar with the techniques employed. This clinical and logistical flexibility makes CRRT the predominant mode to be used, although the utility of intermittent techniques in selected patients is recognised.

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TABLE 1

INDICATIONS FOR SPECIFIC RENAL REPLACEMENT THERAPIES

Therapeutic Goal	Hemodynamic Condition	Preferred Renal Replacement Therapy
Fluid removal	Stable	Intermittent isolated ultrafiltration (IUF)
	Unstable	Slow continuous ultrafiltration (SCUF)
		Peritoneal dialysis
Urea clearance	Stable	Intermittent hemodialysis
	Unstable	CRRT:
		Convection—CAVH, CVVH
		Diffusion—CAVHD, CVVHD
		Both—CAVHDF, CVVHDF
Severe hyperkalemia	Stable/unstable	Intermittent hemodialysis
Severe metabolic acidosis	Stable	Intermittent hemodialysis
	Unstable	CRRT
Severe hyperphosphatemia	Stable/unstable	CRRT

Definition of abbreviations: CAVH = continuous arteriovenous hemofiltration; CAVHDF = continuous arteriovenous hemodiafiltration; CRRT = continuous renal replacement therapy; CVVH = continuous venovenous hemofiltration; CVVHDF = continuous venovenous hemodiafiltration.

Initiation of RRT and an adequate "dose" of RRT

When considering RRT we should be mindful of the following factors:

- Likely time course. A patient with severe sepsis and haemodynamic support will almost certainly still require replacement beyond one week and CRRT is most appropriate. There is little merit in allowing a patient to reach a urea of 20mmoll-1 if they are anuric and acidotic and CRRT is clearly going to be needed in the next few hours/ days.

- Other organ failure or conditions. Haemodynamic instability is the most obvious association favouring CRRT rather than intermittent techniques but one should consider the potential impact on renal recovery, desire to clear middle molecules, associated hepatic dysfunction and anticoagulation

- Likelihood of renal recovery. This is difficult to predict with certainty, but an 80 year old with chronic renal impairment and sepsis is more likely to lose renal function permanently than a 20 year old with pneumonia and sepsis, where permanent renal failure is more typically below 5%. The prospect of lifelong requirement for intermittent dialysis amongst elderly patients following ICU should form part of the decision when offering CRRT.

Given the considerations above we would propose the following empirical parameters as factors prompting active consideration of renal replacement therapy in the critically ill patient:

1) Metabolic acidosis with pH < 7.25. In situations of concurrent respiratory and metabolic acidosis this may require revision and earlier provision.

2) Uraemia, manifest by blood urea > 20 mmoll-1

3) Cation accumulation including acute (<48 hours) K+ >6.0mmoll-1, phosphate >2.0moll-1 or symptomatic hypermagnaesaemia (unusual outside setting of magnesium infusion). The presence of ECG changes makes these thresholds lower and if develops > 48 hours is often better tolerated.

4) Drug or toxin which can be specifically removed by extracoroporeal technology (see below) or other substance eg myoglobin

5) Temperature control. Rarely a patient may have an extracorporeal circuit utilised to aid haemodynamic management and/ or temperature control in conjunction with the parameters above. In pyrexia a core temperature of >40 degrees centigrade should be aggressively treated.

In defining an adequate "dose" of CRRT then we should aim for resolution of the parameters above which prompted initiation of the CRRT ie acidosis (pH at least > 7.25), uraemia (urea < 20), cation accumulation (K+, phosphate and magnesium all in normal ranges) and fluid balance targets met. All these targets may become modified with time or circumstance and should be made explicit on the daily chart for review, and ultimately define an adequate dose of CRRT. The routine collection of urea clearance rates (Kt/V where K is the urea clearance of the system mlmin-1, t is the time min, and V is the volume of distribution of urea, assumed to be the total body water) is not recommended. This parameter is not validated in the critically ill and its calculation unreliable.

Cessation of CRRT

The patient is unlikely to manage without CRRT if they have two or more of the following:

1. Spontaneous urine output < 0.5mlkg-1 hr-1 2. pH
< 7.25
3. K+ > 5.0mmoll-1
4. Urea > 20mmoll-1 or at least not increasing, and plasma creatinine not increasing when filters fail

In identifying patients appropriate for a trial without CRRT it makes sense to do this when the filter fails.
In single organ renal failure, it may be appropriate to discontinue CRRT.
However, if continuing intermittent support is predicted by the clinical scenario, or above criteria, referral needs to be made to the renal team for continued follow up or provision of intermittent support.
Defining and classifying renal dysfunction
While not used in daily practice it is important we have a universal system to classify acute or acute on chronic renal failure and the most commonly used system is the RIFLE classification. This is detailed in the appendix.

Modes of renal replacement in Derby Hospitals Intensive Care Units

A full review is beyond the scope of this document but we should all be familiar with the PRISMA machine and the concepts of CVVH (convection, solute drag) , CVVHD (diffusion) and CVVHDF (both with elements of absorption), pre-and post-dilution. Haemabsorption and albumin based hepatic support techniques (SPAD, MARS, Prometheus) will not be considered here. Therapeutic plasma exchange (TPE) is possible with the PRISMA using a TPE 2000 set, and may occasionally be indicated (HUS/ TTP, GBS, myasthenic crisis).

The selection of modes of RRT are summarised below:
Arteriovenous techniques have been superseded by the development of blood pumps to generate the pressures and flows. Peritoneal techniques are rarely suitable for ICU use, except for occasional elective renal patients already established on this modality. As previously discussed, intermittent techniques can be provided where indicated, but have significant associated staffing implications.

Modes of choice for specific indications

1 Acute renal failure due to severe sepsis/ septic shock in first 72 hours
Mode:CVVHDF
Filter:ST150 Set:
Pre-dilution
Blood flow: 200mls/min
Replacement fluid(=UF rate): Replacement fluid at 1200mls/hr PBP 600
Replacement fluid type: Prismasol 4
Anticoagulation: see anticoagulation section for how to choose.
Fluid Balance: Neutral to positive. Avoid fluid removal during resuscitation and high rates of vasoactive infusions.

Notes:
With pre-dilution sets the formation of ultrafiltrate and addition of replacement fluid represents a dilution process (with a calculable dilution factor) and ultimately loss of efficiency; using higher blood flow rates helps preserve filter life and restore some of the efficiency of pre-dilution ie strive for blood flows of 180 mlmin-1 at all times
The filtration fraction refers to post-dilution sets and depends on blood flow rates (max 200 ml min-1) and the filtration rate (max 4500 ml hr-1) gives filtration fraction 42% at maximal rates, the ideal should be 15- 20%, to avoid promoting in filter clotting secondary to haemoconcentration. We use the 35 mlkg-1 hr-1 replacement setting as a guide only as this came from studies using post-dilution!!!
In setting a replacement fluid rate of 2500mlhr-1 and fluid removal 200 ml hr-1, we actually filter 2700 mlhr-1, replace 2500 mlhr-1 and thus remove 200mlhr-1
.
It is well recognised that initiation of RRT can cause hypotension in these patients. However, slowing of the blood flow rates merely decreases efficiency and promotes filter clotting. The cause is usually vasoactive drug clearance or absorbtion into the filter, vasodilator substance activation by the filter membrance. Generally, it can be predicted that infusion rates will need to significantly increase for the initial period. Fluid shift is not the major issue as the filter is primed and fluid removal rates are not rapid with continuous techniques.

2. Sepsis > 96 hours and/ or ongoing acute renal failure with no pressor requirement.
Mode:CVVHDF 250 PBP 250 replacement and 1500 mlhr-1 dialysate
Filter: ST150 Set:
Standard set
Blood flow: 200 mlmin-1

Replacement/ dialysate fluid type: see below
Anticoagulation: Heparin anticoagulation Fluid
balance: As clinically indicated
Notes:
The most important organ failure dictating the ongoing use of CRRT vs intermittent dialysis is haemodynamic and requirement for vasoactive support. In the presence of inadequate (acid, electrolyte or urea ie small molecule) clearance it is far more efficient to increase the dialysate flow rate rather than the filtration component, and in the presence of excessive clearance rates
may be reduced further and intermittent considered

By using blood flow rates of >180mlmin-1 there will be an element of convection and filtration with modern membranes and so you get a degree of "free"
CVVH anyway!
3 Haemodynamically stable with isolated acute renal failure
Many such patients will have single organ failure and should be considered for intermittent haemodialysis which is more efficient, allows patient mobility and rehabilitation.

4 Poisoning or overdose

Mode:CVVHDF 500 replacement and 2500 mlhr-1 dialysis
Filter: ST100 AN69 filter
Set: pre-dilution set Blood
flow: 200 ml/min.
Replacement/ dialysate fluid type: see guidance below
Anticoagulation: Heparin anticoagulation
Fluid balance: As clinically indicated

See appendix for substances which may be removed by haemodialysis
We do not frequently admit patients to provide isolated extracorporeal drug or toxin removal, but agents which may be amenable to such therapy are listed below. Intermittent dialysis techniques are by far the most efficient.
Monitoring
Most monitoring is routine in the intensive care unit and occurs in the absence of CRRT anyway. However,
U+E should be 6 hourly initially, then may be increased to 12- 24 hours if stable
ABG at least 6 hourly and as indicated
Vital signs and temperature, urine output
Monitoring of coagulation parameters is considered below

The removal of a urinary catheter following 48 hours of established anuria is recommended and it may be re-passed intermittently every 48- 72 hours to exclude residual volume. If this is the case the bladder should be scanned every 24 hours to exclude a residual volume and obstruction.

Vascular access

Choice of sites

We no longer practice arterio-venous techniques and access uses a same vessel veno-venous catheter. Good blood flows are the essential basis and solution for many of the problems encountered. Hence, we need to be extremely fussy about venous acces lines. The following should be considered when placing a line for CRRT:

Site	Advantages	Disadvantages
Right internal jugular	Allows access to the proximal SVC or right atrium Straight line with little prospect of kinking Familiar site Compressible Semi-familiar site	Existing access often present Patient mobility may kink/ displace line
Left internal jugular		Left handed insertion Ends up "short" of SVC or RA and tenting of great vessels
Femoral	High flow rates with good efficiency Familiar site Can be compressed if bleeding	Can kink with flexion of leg (ventilator bundle) Possibly higher rates infection (controversial)
Subclavian	Externally "stays put" Lower rates of infection	Can be technically difficult Non-compressible Kinks between clavicle and first rib May not be able to pass catheter after venotomy Fistula formation Becoming less familiar

From this it can be seen that the femoral vessels and the right internal jugular vein are the preferred sites. The insertion technique should follow the unit and

Trust guidance and should include aseptic technique, ultrasound guidance and confirmation of venous placement before dilatation.
The manufacturer's recommendation is that Niagara femoral lines be routinely replaced at 72 hours, as an infection risk. We would reject this and apply the central venous catheter policy which suggests changing only when concerns exist regarding infection eg discharge at insertion site. Furthermore, dialysis lines are probably less likely to be infected due to regular/ continuous high volume flushing in use, akin to arterial lines.

Types of catheters

All catheters should be able to handle flow rates in excess of 200mlmin-1 and allow for single vessel access, with intermittent machines and their larger filters the blood flow rates can be higher 3- 400 mlmin-1. We have settled upon:

Prisma Access lines

24 cm for femoral
20 cm for internal jugular or subclavian
(Occasionally a 15cm line may be more appropriate for very short patients but not for a left internal jugular insertion).
These are 13.5 Fr non-compressible dedicated CRRT lines with excellent flow properties, but be aware the 3.0 cm staggered tip means that reversing the arterial/ venous access results in dramatic reduction in efficiency (up to 30% re-circulation rates) and potentially reversed vessel blood flow.
(Vygon Trilyse Expert. We anticipate the phasing out of these lines.
These have three lumens, two for CRRT and one for administration, in a 12 Fr catheter of 15 cm length. Note the proximal port (red) will allow faster flow rates than the distal. These are silver impregnated catheters. These lines
tend not to provide such fast flow rates and give higher access pressures, and a third lumen runs the risk of increased line infections).

Position

Femoral The 24cm femoral catheter should be inserted to the maximum depth and syringe tested before final suturing.

Upper body catheters Classically, the tip of the catheter should be above the carina on a CXR to avoid sitting within the pericardial reflection, hence minimising the risk of tamponade. Placing or allowing a catheter to sit within the higher flows of the right atrium, to achieve effective filtration is acceptable practice and also used in chronic dialysis. The small risk of rupture and tamponade is offset by the increased mortality of ineffective RRT, and certainly do not remove a line which is otherwise working well if it is discovered to be within the right atrium.

The manufacturer recommends the Niagra line should have the venous (return) port in the medial position ie adjacent to the head when placed in the internal jugular.
Syringe testing Once inserted it is good practice to attach a 20ml syringe and

aspirate and return 20ml of blood as quickly as possible. If this cannot be achieved within 5 seconds or so it is highly unlikely the roller pumps will manage to get 180 mlmin-1 out of it. The perfect line is the one which provides high blood flow rates with the lowest possible access pressures and continues to do so for 24 hours per day!

Sequence of events and "locking" lines

At present it is common practice to insert the line, confirm placement and then run through the PRISMA set. While this ensures sets are not wasted if access proves difficult, the economic saving of a filter vs a line is small and there are real benefits to connecting directly to the line and ensuring patency.
Accepting the unit is often busy and staff limited, where possible we propose that as the line is being sited the PRISMA set should be run through so it is available to connect directly. It is the responsibility of the clinician inserting the line to ensure they are confident to do so (ie confirm venous placement) and having ensured adequate flow rates can be achieved, the line may be secured in the optimal position. A confirmatory radiograph for internal jugular or subclavian lines may be delayed until this occurs.
If there is any delay in attaching the circuit to the line, it should be locked using the stated prime volume on the line with 5,000 iuml-1 heparin, which should be aspirated before connection. For safety purposes all RRT lines should be assumed to be filled with heparin lock and should be aspirated prior to any administration or connection of CRRT circuit.
Note once a PRISMA set has been primed, if it cannot be connected immediately then it will require re-priming with 500ml of priming solution. The standard priming solution is 1l 0.9% saline with 5,000iu unfractionated heparin, and this is used twice (ie 2.0 litres run through).
A line that does not provide reliable flows will cause multiple problems and may present with either access pressure issues or filter clotting problems. Reversing lumens is an option, but will adversely affect efficiency through re-circulation, particularly with non-circumferential catheters. It is far better to replace or resite these lines early

Choice of filters

AN-69

Our routine CVVHDF filter is the polyacrylonitrile ST150 pre-dilution set with a capacity of 103ml surface area 1.5 m2.
Sieving coefficient: (bovine plasma, Pc 60 g/l, T=37%C), QB =100 ml/min,QUF =20 ml/min

Urea =1
Creatinine =1
Vitamin B12 =1
Inulin =0,95
Myoglobin =0.55
Albumin ≤0.01

This low surface area filter will not tolerate the pressures required for high flow CVVH, and there is no benefit in filtration rates in increasing TMP > 300mmHg. The AN-69 is in reality a relatively high flux membrane and, especially when combined with 180mlmin-1 blood flow, offers a degree of convective clearance.

This ultrafiltrate formation rate 51 mlmin-1 is equivalent to 3060 mlhr-1. This filter is poorly suited to high flux CVVH, and appropriate for CVVHDF.

Maintaining filter life and anticoagulation

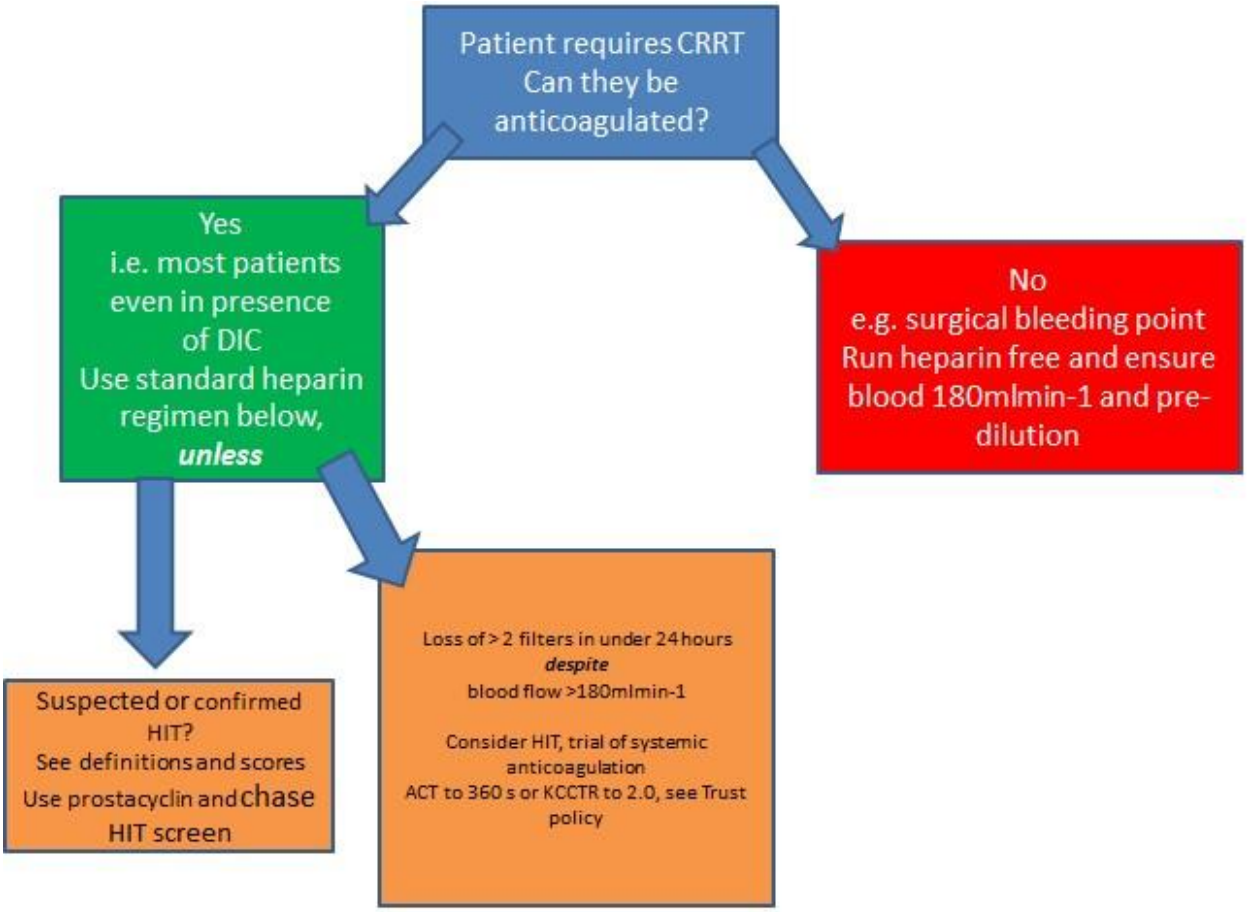
We expect at least 24 hours out of a filter and would not be surprised to see >72 hours on occasions, although the manufacturer's recommend the sets are routinely changed at this point. We plan to deliver this using:

1) Excellent vascular access
2) Maximal blood flow rates 180mlmin-1
3) Pre-dilution sets (efficiency reduced approx 15%)
4) Judicious use of anticoagulants

It should be noted that much of the early clearance, especially of middle molecules, has been ascribed to filter adsorption rather than convection or diffusion and this is saturable, typically after 6 hours or so.

Patient requires CRRT

Can they be anticoagulated?



Standard heparin regimen

Standard prime of circuit with 2 X1.0l containing 5,000iu heparin
Followed by an infusion of 10 iukg-1 hr-1 (lean body weight) in conjunction with blood flow rates 180 mlmin-1 and pre-dilution sets. The ideal body weight (IBW in kg) is calculated using:
IBW men= height (cm)- 100
IBW woman= height (cm)- 105

A 165 cm tall woman therefore has an IBW 60 kg, and would receive 600 iuhr-1of unfractionated heparin by infusion. If the patient cannot be laid supine for this measurement, the distance from the tip of fingers of an extended arm to the midline ie sternum may be measured. This is the hemispan and if doubled should = height.
This regimen does not aim to produce systemic anticoagulation and the ACT or KCCT may be checked every 24 hours unless evidence of bleeding complications and it should be checked more frequently.
This should be the default setting for heparin use and used for all patients unless contraindicated or filters are being lost on a recurrent basis. The commonest reason for deranged clotting in ICU is disseminated intravascular coagulation (DIC: strongly suggested by raised D-dimer concentrations, see diagnostic criteria in appendix) and paradoxically thrombotic risks and filter occlusion are more common. Deranged coagulation on the basis of DIC is an indication for heparin use. If filters are being lost at < 1 day or > 4 days of starting heparin infusion consider HIT as a cause as this may precede the thrombocytopenia by a period of days.

Systemic heparinisation

If the regimen above proves unsuccessful (defined as the loss of > 2 filters in under 24 hours, provided adequate access and flows are used) consider moving to a systemic anticoagulation of the patient with heparin targeting an ACT 2 times normal (ie up to 360 seconds) or a KCCTR of 2.0 and using the existing Trust protocol. If systemic anticoagulation with heparin appears to be failing (ie inability to get KCCTR 2) with subsequent loss of filters, consider checking antithrombin III (ATIII) levels and administering FFP.
Note however that thrombosis often precedes thrombocytopenia during HIT, so it is mandatory to send a HIT screen and perform the 4T's screen with frequent filter loss, see appendix on HIT.`
Circumstances to consider avoiding heparin use

1) Heparin induced thrombocytopenia (HIT). See appendix for diagnostic criteria for HIT. Note that enoxoparin and LMWH are not suitable in cases of suspected/ confirmed HIT. For such patients use prostacyclin (heparin at 1000iuhr-1 costs £5.20 and prostacyclin at 2.1mlhr-1 costs £76.00 day-1).

2) Recurrent filter clotting during heparin use, despite achieving KCCTR 2. Be aware that this may be a sign of HIT before thrombocytopenia develops, consider prostacyclin until diagnosis of HIT excluded.

3) Clopidrogrel GPIIb/IIIa antagonists or similar anticoagulant or

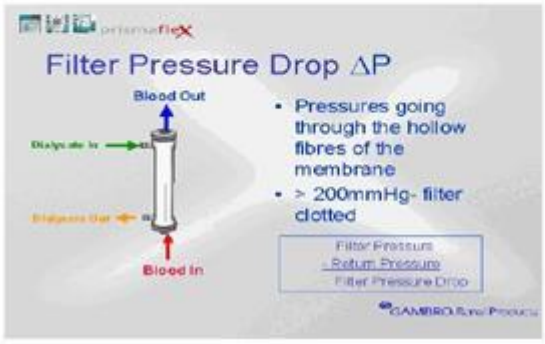
antiplatelet therapy, or co-incidental coagulopathy eg liver disease or thrombocytopenia. Generally avoid systemic anticoagulants.

4) Severe bleeding risk at anatomically dangerous site (eg brain or retroperitoneum) or clinically significant bleeding episodes eg upper GIT or

Under these circumstances a number of options present themselves:

- Heparin free
- Prostacyclin
- Combined heparin/prostacyclin
- Non-standard e.g. Citrate, Hirudin. (Rare and guidance provided if used)

A clotting filter is rarely missed and will become apparent by:
1) The appearance of dark swirls within the filter is an early sign of debris accumulation; they usually run for a period of time beyond this
2) TMP > 450 mmHg
3) Filter pressure drop >200mmHg
The initial advisory alarm "filter is clotting" should prompt check for line kinks, air leak between return pod and return housing, and a pod re-positioning may help. The warning alarm "filter is clotted" means it is too late and unless the lines are clamped a new set will be required. Review the settings and access, flows and anticoagulation, the choice of filter being used and whether CRRT is still required.



Replacement and dialysate fluids

A variety of solutions are now available for use and, despite being cheap as individual units, due to volumes which we can get through, constitute a significant ICU cost. The contents of these solutions are given in the appendix. The routine replacement and/ or dialysate fluid should be: Prismasol 4.

Situations where Monosol(Lactate solutions) should be used with caution include:

1) Lactic acidosis at presentation, of whatever cause. Use Prismasol 4 exclusively and review when lactate < 5.0mmoll-1
2) Hepatic decompensation/ failure. Unless lactic acidosis at presentation, it is reasonable to give a trial of Monosol and stop if lactate > 5mmoll-1. If this is the case run alternate bags of Prismasol and Monosol K, and if lactic acidosis persist use exclusive Prismasol. Review the solution at 24 hours.

We have available a largely lactate free solution (Prismasol 4, contains K 4.0 and 3.0mmoll-1 lactate). The liver and kidney can clear 100mmol lactate per hour in health, although this will be reduced in critical illness through hepatic (and renal!) failure. The use of lactate free replacement/ dialysis fluid should be considered when the plasma lactate exceeds 4- 5.0 mmoll-1 when using lactate containing fluids at a rate required to ensure clearance. There is little direct evidence that hyperlactataemia is damaging, and it is rarely a source of acidosis as it is buffered. Furthermore, if infusing lactate at 30mmoll-1 and the plasma concentration is static at < 5mmoll-1, it is being hepatically metabolised. The metabolism of lactate consumes protons and releases glucose. Prismasol is significantly more expensive that Monosol (approximately £8 per bag, which if using 3000 mlhr-1 of replacement represents an excess of £100 per day!) Also be aware that it contains 4.0 mmoll-1 of potassium

The rates and volumes of these two types of solutions are interchangeable if a change is made and don't need adjusted.

Fluid balance and considerations

The target fluid balance is one aspect of care which makes CRRT very attractive; in the presence of oligo/ anuria fluid is typically to be removed and CRRT allows this to occur over 24 hours rather than a 3-4 hour intermittent session.

Note during CVVH the removal incorporates the replacement rate ie 2500 mlhr-1 replacement with 100mlhr-1 fluid removal actually puts 2600mlhr-1 across the filter.

Because we provide multiple organ support in ICU and fluid balance has such profound effects on the haemodynamic and respiratory systems in addition to the renal system, it is most appropriate that the target fluid balance is determined by the intensive care team while in the ICU.

Beware setting fluid removal for patients who are receiving vasoactive infusions, especially pressors. It is usually appropriate early in an ICU course of multiple oragn failure and shock to allow patients to become positive, and attempts to remove fluid generally result in hypovolaemia and increased vasoactive doses. Conversely, during a prolonged ICU stay (>5 days) with prominent respiratory failure a negative balance is desirable and the absence of a need for vasoactives usually identifies this change. As a general guide it is not possible to move tissue fluid to the circulating volume at > 400mlhr-1 and so fluid removal should not be above this setting: 200mlhr -1 removal is a significant setting and would equate to 5.0l off in 24 hours!

Confusion has existed previously regarding what to count in the fluid balanceeg inclusion of crystalloid as "input" but exclusion of blood which will not undergo filtration. For the purposes of clarity we would strongly suggest that raw totals for input and output are recorded, and clinicians may determine the significance of different fluids eg colloid vs crystalloid afterwards.

Drug prescribing on CRRT

The actual clearance rates delivered by CRRT typically equate to a GFR of 20- 25 mlmin-1 and modern membranes are relatively "high flux". It is generally inappropriate to prescribe as if the patient were in chronic renal failure and receiving intermittent dialysis as this will produce undertreatment.
The decision on what dose of a drug is influenced by:

1) The likely consequence of inadequate treatment. In the case of an antibiotic it is generally more harmful to undertreat and not achieve tissue MIC
2) The likely consequence of an overdose. If the agent considered is relatively safe in overdose eg cefuroxime then the clinician may chose to maintain doses, in contrast to a more harmful agent eg gentamicin or vancomycin.
3) The ability to measure plasma concentrations. Empirical dose changes become irrelevant if the concentration of the drug may be tracked eg gentamicin or vancomycin.

At present we use the Network guidelines for doses which are available from Stuart Parkes, and in general use higher doses (which we support!) than appear elsewhere in the literature.
Measurable outcomes and audit of CRRT provision
We have a need for an ongoing audit programme for the provision of CRRT and it is hoped that future order sheets will allow easy collection of audit data.

We would recommend the following parameters are collected to review and subject to audit:
Acidosis resolution
Hyperkalaemia, phosphate
Filter life ie time from patient connection to filter clotting and need to change
Fluid balance
Total duration of CRRT, recovery of renal function or discharge for intermittent haemodialysis
Vasoactive doses 17

Nutritional and negative aspects of CRRT

As the use of CRRT allows the clearance of detrimental ions and small/ middle molecules eg urea or potassium, so it removes and clears more beneficial substances eg trace elements, phosphate, water soluble vitamins. It is important therefore that patients who are on CRRT receive:

1) Pabrinex 2 amps 8hrly
2) Folic acid 5mg ng (or iv if not absorbing enteral feeds)
3) Trace elements (Additrace ampoule once daily)
4) Cation repletion. Phosphate is poorly removed by intermittent techniques- it tends to disappear with CRRT. Replacement doses may be considerable approaching 1-2 mmolkg-1 day-1
5) Iron replacement. We must be mindful the failing kidney will rarely produce erythropoietin.
6) Consideration of nitrogen loading- policy to be developed

It is essential that nitrogen and nutrition are not withheld to avoid "worsening"

renal failure, in the presence of acute renal failure.
For patients with chronic renal (and liver) failure this may not be the case and individual prescriptions should be issued, mindful of intermittent dialysis schedules.
There is some evidence that vitamins K and B12 may require replacement during prolonged/ high volume CRRT.
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Appendix

Diagnostic criteria for Heparin induced thrombocytopenia (HIT)
Please refer to guidance on intranet regarding 4T's testing. HIT screens and sunbsequent management. Beware recurrent clotting can be a presenting feature of HIT and HITTS, days before thrombocytopenia develops.
Diagnostic criteria for Disseminated Intravascular Coagulation (DIC)
DIC may be defined as a pathological state of concurrent activation of the platelet and thrombotic pathways and fibrinolytic pathways. As such one of the hallmarks is the detection in blood of fibrin degradation products reflecting both formation of thrombus and its breakdown.
The International Society of Thrombosis and Haemostasis (ISTH- an anagram or initials? http://www.med.unc.edu/isth/) score uses readily available parameters to diagnose DIC and has been validated for use in ICU, where a score of 5 or more is suggestive of overt DIC, but may lack sensitivity for non- overt DIC! This score should be used for conditions commonly associated with DIC (eg sepsis) and should be avoided if venous thrombosis, pulmonary
embolus. Similarly it lacks sensitivity in diagnosing DIC in patients with severe sepsis/ septic shock.
We therefore propose to diagnose DIC at Derby by the presence of all 4 of:

1. Identification of a condition which commonly causes DIC (see below)
2. Thrombocytopenia or a fall > 20% (not due to other causes)
3. Elevation of D-dimer
4. Prolongation of the prothrombin time beyond the upper limit of normal or increase > 0.3 s

Conditions seen at Derby Hospitals which commonly cause DIC

1) Severe sepsis/ septic shock
2) Trauma including polytrauma, brain injury or fat embolus syndrome
3) Organ destruction eg pancreatitis
4) Malignancy inc solid tumours or haematological/ lymphoproliferative
5) Obstetric disasters including pre-eclampsia, amniotic fluid embolus, placental abruption
6) Vascular abnormalities including AAA with thrombus
7) Severe hepatic failure
8) Transfusion reactions

For reference purposes the ISTH criteria are included below:

For reference purposes the ISTH criteria are included below:

table 2: Diagnostic algorithm for the diagnosis of overt DIC

1. Risk assessment: Does the patient have a underlying disorder known to be associated with overt DIC?
   If yes: proceed; If no: do not use this algorithm;

2. Order global coagulation tests (platelet count, prothrombin time (PT), fibrinogen, soluble fibrin monomers or fibrin degradation products)

3. Score global coagulation test results
   - platelet count *(> 100 = 0; < 100 = 1; < 50= 2)*
   - elevated fibrin-related marker (e.g. soluble fibrin monomer or fibrin degradation products) *(no increase: 0; moderate increase: 2; strong increase: 3)*
   - prolonged prothrombin time *(< 3 sec = 0; > 3 sec. but < 6 sec = 1; > 6 sec. = 2)*
   - fibrinogen level *(> 1.0 gram/l = 0; < 1.0 gram/l = 1)*

4. Calculate score

5. If ≥ 5: compatible with overt DIC; repeat scoring daily
   If < 5: suggestive (not affirmative) for non-overt DIC; repeat next 1-2 days;

Uncontrolled when printed

The RIFLE criteria

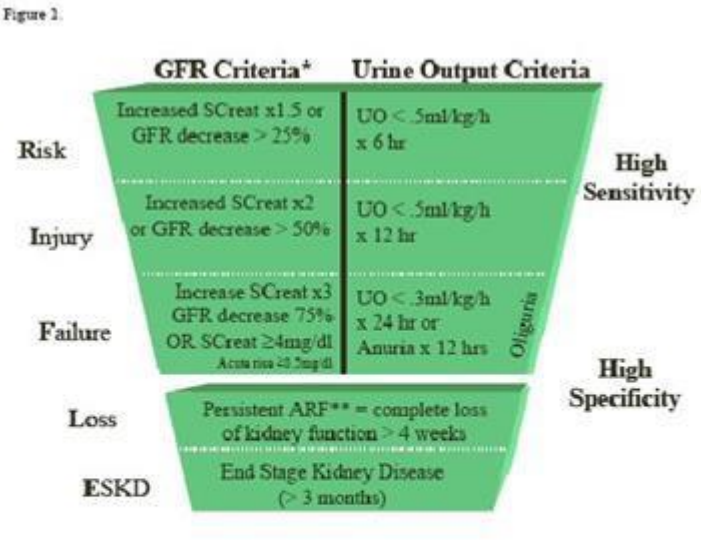


Figure 1. Proposed classification scheme for acute renal failure. The classification system includes separate criteria for creatinine and urine output. The criteria that leads to the worst classification should be used. Note that RIFLE-F is present even if the increase in S_{Cr} is < 3 fold so long as the new S_{Cr} is ≥ 4.0 mg/dL (350 mcmol/L) in the setting of an acute increase of at least 0.5 mg/dL (44 mcmol/L). The designation RIFLE-F_C should be used in this case to denote "acute-on-chronic" disease. Similarly when RIFLE-F classification is reached by urine output criteria, a designation of RIFLE-F_O should be used to denote oliguria. The shape the figure denotes the fact that more patients (high sensitivity) will be included in the mild category, including some without actually having renal failure (less specificity). In contrast, at the bottom, the criteria are strict and therefore specific, but some patients will be missed.

<u>Acidic toxins which may be eliminated by extracorporeal technology</u>

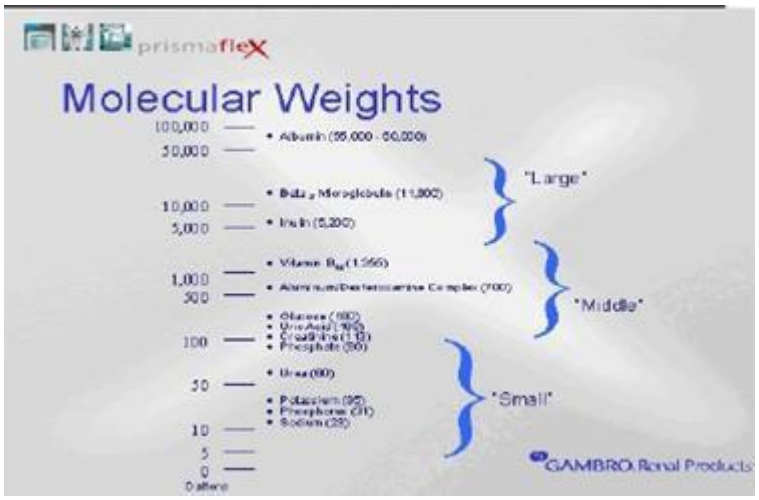
Theophylline
Phenobarbitone
Lithium
Alcohol, methanol, ethylene glycol, ketones
Aldehydes (paraldehyde and formaldehyde)
Salicylates
Myoglobin
Bilirubin*
Metformin
Carbamazepine, phenytoin, valproate
Theophylline
Methotrexate
Paraquat (controversial), Amatoxines* (controversial)
Toluene (hippuric acid)
Most ingested toxins have a molecular weight < 2000 Da and thus are freely permeable across modern membranes. To be appropriate for extracorporeal 21 removal agents should exhibit a low volume of distribution, minimal protein binding.

Replacement fluids and contents (mmol/L)

Constituent	Monosol K	Monosol	Prismasol 4
Osmolality	301	293	301
Sodium	140	140	140
Potassium	4	0	4
Chloride	119	115	113.5
Lactate	30	30	3
Calcium	1.75	1.75	1.75
Magnesium	0.75	0.75	0.5
Glucose	5.55	5.55	6.1

Drug dosing during CRRT

Continuing development in this area, at preset use the MTCCN guideline unless indicated otherwise. Most CRRT delivers GFR equivalent to 25% of GFR or so.
Molecular weights of commonly encountered substances
The cut-off for a filter is defined as the molecular weight where < 10% of the substance can be filtered.



http://www.lhsc.on.ca/critcare/icu/protocols/index.html
http://www.hospal.com/intensivecare/main_421l.html
www.crrtonline.com

Documentation Control

Development of Policy:	Dr. Craig .Morris (Consultant Intensivist) and Practice Development. 2014 revision: Dr. Nick Reynolds (Consultant Intensivist)
Consultation with:	Consultant Intensivists
Approved by:	**Dr. James Low (Lead Clinician)**
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Key Contact:	Dr. Nick Reynolds **(**Consultant Intensivist)

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