CRRT
Aquarius Filtration

Clinical
Practice Guidelines
# EXTRACORPOREAL FILTRATION

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Troubleshooting Aquarius Alarms see red attached folder
WELCOME TO THE WORLD OF CONTINUOUS RENAL REPLACEMENT THERAPY

This clinical guideline package has been put together to endeavour to supply the user (both medical and nursing) with the protocols and information to safely and effectively manage continuous renal replacement therapy or therapeutic plasma exchange.

In PICU we have been using continuous renal replacement therapy (CRRT) since 1993. Our primary methods of filtration within PICU are Continuous Veno-Venous Haemofiltration (CVVH) and Continuous Veno-Venous Plasmapheresis (CVVP)/Therapeutic Plasma Exchange (TPE).

Our total numbers of continuous renal replacement therapy remain very low when compared against the adult world. From 1993 - 2007 there have been 156 children filtered in PICU. This is an average of 11 patients per year.
EXTRACORPOREAL FILTRATION

AQUARIUS QUICK START

1. Plug into mains power and ensure power switch on [I] at the lower L) side of the machine.
2. Turn machine on at the R) side of the main screen. [Depress key for 2-3 seconds.]
3. Allow machine to commence "SELF TEST". This will take approx 5 minutes.

No tubing or bags to be on Aquarius or scales during this time and doors must be closed.
All doors must be shut.
If the self-test appears to be taking a long time – switch off and start again.

CONSUMABLES

✓ 1x Aqualine (>30kg)/Aqualine S (<30kg) tubing set
✓ 1x Aquamax filter (<10kg = HF03, 10–30kg = HF07, >30kg = HF12 or MPS05 Plasmfilter)
✓ 1x Bag spike
✓ 1x Hotline tubing
✓ priming fluid – 2x 1000ml 0.9% Sodium Chloride
✓ substitution fluid (+ multi-bag spike pack & extra ultrafiltrate bags if hanging more than one bag
  of substitution fluid)
✓ 3x large bore 3-way taps and 3x Smartsites (1x red & 2x blue)
✓ 2x 10ml syringes

ANTICOAGULATION

CVVH – Citrate based substitution fluid
5l bag(s) of citrate based substitution fluid
Remember to make up the Calcium Gluconate infusion and run via CVL access

CVVH - Heparin
- Heparin infusion in 50ml BD precise syringe
- ACT machine & LR cartridges

CVVH - Heparin & Iloprost
- 1x 3-way tap
- 1x extension tubing
- 1x Alaris syringe pump
- Heparin infusion as per protocol (page 30) in 50ml BD Precise syringe
- Iloprost infusion as per protocol (page 32) in 50ml BD Precise syringes
- ACT machine & LR cartridges

TPE
- Heparin infusion as per protocol in 50ml BD Precise syringe
- ACT machine & LR cartridges

Remember to order the FFP and 4% Albumin
# EXTRACORPOREAL FILTRATION

## CATHETERS, FILTERS & CIRCUITS

### CATHETERS

Maximum blood flow rate achievable will vary with catheter size & machine.

Approximate ranges for the different catheters are:

<table>
<thead>
<tr>
<th>Size</th>
<th>Flow Rate</th>
<th>Use For</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5F</td>
<td>20-80mls/min</td>
<td>Up to 10kg</td>
</tr>
<tr>
<td>8.5F</td>
<td>50-120mls/min</td>
<td>11-29kg</td>
</tr>
<tr>
<td>11F</td>
<td>90-250mls/min</td>
<td>30+kg</td>
</tr>
</tbody>
</table>

### FILTERS

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>HF03 (Haemofilter)</td>
<td>0 – 10 kg, 32ml</td>
</tr>
<tr>
<td>HF07+ (Haemofilter)</td>
<td>10 – 30 kg, 54ml</td>
</tr>
<tr>
<td>HF12 (Haemofilter)</td>
<td>30+ kg, 73ml</td>
</tr>
<tr>
<td>MPS05 (plasmafilter)</td>
<td>One size only, 50ml</td>
</tr>
</tbody>
</table>

### CIRCUITS

<table>
<thead>
<tr>
<th>Circuit Type</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aqualine S</td>
<td>0 – 30 kg, 64ml</td>
</tr>
<tr>
<td>Aqualine</td>
<td>30+kg, 105ml</td>
</tr>
<tr>
<td>Hotline</td>
<td>One size, 20ml</td>
</tr>
</tbody>
</table>
RATIONALE FOR CRRT

Introduction
The concept behind continuous renal replacement techniques is to mimic the renal function of patients in a physiologic way, with continuous filtration, until no longer required. Intensive care patients are particularly suited to this technique as they are, by definition, bed bound, and, when acutely sick, intolerant of the fluid swings associated with intermittent haemodialysis (IHD).

Common reasons for Filtration in PICU are:
- Renal Failure with
  - Fluid overload
  - Hyperkalemia
  - Acidemia
  - Severe uremia
- Removal of Toxins
  - Drug toxicity (non-plasma bound)
  - Inborn errors of metabolism

Advantages:
- Well tolerated cardiovascularly
- Fine control over fluid and electrolyte shifts
- Effective urea clearance and controlled fluid removal.
- Creates room for essential fluids such as blood products and nutrition.
EXTRACORPOREAL FILTRATION

Setup and Programming
The configuration of the haemofiltration circuit will vary slightly, depending which anticoagulation protocol is selected.

CRRT WITH CITRATE-BASED SUBSTITUTION FLUID

Setting up the Circuit using the Haemofiltration Solution Citrate (14mmol/litre) based Anticoagulation Protocol

1 x Aquarius machine
1 x Aqualine set (<30kg = Aqualine S, >30kg = Aqualine)
1 x filter (<10kg = HF03, 10-30kg = HF07, >30kg = HF12)
1 x bag spike
3 x large bore 3-way taps and 3 x Smartsites (2x blue and 1x red)
2 x 1000ml 0.9% Sodium Chloride (priming fluid)
1 x Hotline tubing and Hotline unit
1 x 10ml syringe
1 x 5l bag Haemofiltration Solution Citrate fluid (substitution fluid) + multi-bag spike (manifold) if hanging more than one bag of substitution fluid
(Remember extra U/F bags and multi-bag spike if hanging more than one bag of replacement fluid)

Instructions

- Turn on the Aquarius and await completion of self-test.
- If this is unsuccessful, ensure all the doors are closed and nothing is hanging on the scales and select Restart’ turn the Aquarius or off turn & back on to repeat the self-test.
- Select therapy – CVVH
- Select Aqualine S paediatric circuit (<30kg) or Aqualine circuit (>30kgs).
- Set up the Aquarius as per the machine on screen instructions.
- Ensure that Hotline tubing and large bore 3-way tapes are placed into the circuit, as per photo overleaf, prior to priming. (They are not a part of the screen instructions.)
  - Place the Hotline tubing between the return (blue) line and the bag spike.
  - Place the 2 large bore 3-way taps into the circuit between the Hotline tubing and the bag spike. Cap the free ports of taps with blue Smartsites.
o Place the remaining large bore 3-way tap between the priming bag and the access (red) line. Cap the spare port of the tap with a red Smartsite.

Instructions continued

- Ensure that the degassing chamber is firmly inserted in the degassing unit with the hydrophobic filter line positioned toward the front of the unit. Ensure that the line is clamped until the substitution line is fluid filled and the lid is pushed down firmly. Unclamp hydrophobic filter line once Aquarius in recirculating mode.

- Commence the priming procedure as per the Aquarius screen instructions.

- Ensure that the circuit Heparin line is flushed with 0.9% Sodium Chloride and has a blind end cap on the end.

- Once the circuit is primed, Edwards Life Science recommend recirculation at a blood flow rate of 50mls/hr for at least 20 minutes prior to connection, in order to fully “wet” the filter fibres.
EXTRACORPOREAL FILTRATION

CRRT WITH CITRATE-BASED SUBSTITUTION FLUID

Programming

- The PICU Consultant/Fellow must write the filtration prescription on the Filtration Record.
- The Aquarius will account for all fluids on the scales plus the circuit heparin infusion (if running), but not the patient IV & enteral fluids & drugs. Therefore, to achieve the hourly fluid balance target - add up all fluids (this includes bolus medications – e.g. drugs & flushes) infusing into the patient. This total plus the desired hourly fluid balance of the patient, gives you the total to set for the Fluid Loss Rate (ml/h). This is the number you titrate to pull off more or less fluid each hour.
- It is also necessary to set an ‘end goal’ target. Once you have set your Fluid loss rate you can then set your Total Fluid Loss goal. This ‘goalpost’ can be adjusted as needed.
- In CVVH mode programme the Predilution ml/hr volume only.
- Continue to programme the Aquarius as per the programming screen.
- Ensure that if the Hotline is in the circuit that the Aquarius hotplate is turned off.
- Cumulative totals are cleared every morning at 0700 hours by selecting ‘Reset Totals’.

![Programming Screen]

CITRATE ANTICOAGULATION FOR HAEMOFILTRATION

Patients on continuous modes of renal replacement therapy require anticoagulation to prevent clotting of blood in the extracorporeal circuit. Adequate anticoagulation prolongs circuit life but how long the membrane remains effective is debatable. Citrate is the anticoagulant of choice in PICU. Citrate anticoagulation prolongs circuit life and causes less bleeding when compared with Heparin.
Citrate anticoagulation

Citrate acts by chelating (binding) calcium ions that are essential in the clotting cascade. It also chelates other divalent cations including magnesium and aluminium.

A plasma citrate concentration of about 5-6mmol/L is required in order to reduce ionised calcium concentration to less than 0.6mmol/L, which is required for anticoagulation. Adding approximately 2-3 mmol of citrate per litre of blood flowing through the filter usually achieves this.

Most of the added citrate returns to the patient and is metabolised rapidly by the liver, though there is a continuously slightly elevated systemic plasma citrate level which chelates some calcium in the systemic circulation. This can lead to a low systemic ionised calcium level even with normal total calcium. Also some chelated calcium is filtered, and as the substitution fluid contains no calcium there is a net loss of approx 2-3mmol/kg/day in the filtrate.

In order to avoid systemic ionised hypocalcaemia, a separate infusion of calcium is required at a rate of approximately 2mmol/kg/day for a blood flow of 5ml/kg/min, and this is adjusted to maintain systemic plasma ionised calcium level of approximately 0.9-1.2mmol/L.

To achieve optimal anticoagulation within the circuit using a citrate based substitution solution there must be a balance between circuit blood flow and substitution fluid flow rate. This ratio between citrate dose and circuit blood flow remains reasonably fixed allowing the prediction of what citrate dose (substitution flow rate) is needed for a particular blood flow rate.

Magnesium supplementation will be necessary. This may be as a separate magnesium infusion or by intermittent blousing.

Citrate is metabolised to bicarbonate (three molecules per molecule of citrate), mostly in the liver. A metabolic alkalosis therefore develops in protocols which add citrate separately (even when some of the citrate is as citric acid, e.g. acid-citrate dextrose), and hypernatraemia if the citrate is added as trisodium citrate. This is minimised if sodium citrate is an integral component of the substitution fluid where the citrate acts as the base compound instead of bicarbonate. This only happens if the liver is able to metabolise the citrate load.
CITRATE ANTICOAGULATION FOR HAEMOFILTRATION CONT.

Relative Contraindications

Citrate anticoagulation may NOT be an option for:

- Patients with severe hepatic dysfunction – e.g. fulminant liver failure.
- Patients with coagulopathy (ACT >200 sec, or APTT > twice normal) may be filtered without any anticoagulant using the bicarbonate-based substitution fluid Accusol and a maximum tolerated Blood flow rate (BFR). E.g. liver failure, overwhelming sepsis.
- Patients with “Citrate lock”, where citrate has accumulated during citrate anticoagulation. These patients may use Heparin as an alternative anticoagulant (see page 25).

Substitution Fluid

Made commercially in 5 Litre bags by Baxter/Edwards Life Sciences.

Composition cannot be adjusted, except for the addition of potassium chloride, potassium phosphate, or sodium phosphate, if needed, as per CVVH protocol.

Potassium should be added to the substitution fluid to maintain the serum potassium @ 4mmol/l. This can be achieved by adding either KCl or KH₂PO₄ to each 5 litre bag to achieve a concentration of 20mMol in a 5l bag.)

The composition is:

- Sodium 140mmol/L
- Potassium 1mmol/L
- Chloride 99mmol/L
- Citrate 14mmol/L (42meq/L) Trisodium citrate dihydrate.

ALL the substitution fluid must be added Pre-Filter, never Post-Filter to ensure that the filter and circuit are anti-coagulated.
PERFORMING CVVH with CITRATE ANTICOAGULATION

Step 1
Blood Flow Rates

For citrate anti-coagulation to be effective it is essential to match the substitution flow rate to the blood flow rate, as per the table below.

Table 1:
Initial blood flow rates and substitution fluid flow rates for under 50kg

<table>
<thead>
<tr>
<th>INITIAL Substitution flow rate</th>
<th>35ml/kg/hr</th>
<th>48ml/kg/hr</th>
<th>56ml/kg/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood flow rate</td>
<td>4ml/kg/min</td>
<td>5ml/kg/min</td>
<td>6 ml/kg/min</td>
</tr>
<tr>
<td>INITIAL 10% Ca Gluconate infusion rate</td>
<td>0.3 ml/kg/hr</td>
<td>0.36ml/kg/hr</td>
<td>0.42ml/kg/hr</td>
</tr>
<tr>
<td>Approximate clearances of urea/creatinine</td>
<td>40ml/kg/hr</td>
<td>50ml/kg/hr</td>
<td>60ml/kg/hr</td>
</tr>
</tbody>
</table>

[The initial BFR to substitution fluid ratio is approximately 1ml/kg/min BFR : 9ml/kg/hr substitution fluid.]

[The 10% Ca Gluconate infusion rate to BFR is approximately 1ml/kg/min BFR : 0.07ml/kg/hr]

- For effective solute clearance to occur the minimum substitution fluid rate is 35ml/kg/hr.
- The blood flow rate (BFR) must be maintained at 20ml/min or greater to prevent stasis and clotting.
- For a child already on a Calcium Gluconate infusion you may utilise the existing infusion – increasing the rate to the calculated initial rate if needed.
- The desired BFR is established first and then the substitution fluid and Calcium Gluconate infusions are commenced at the appropriate rate within 15 minutes of commencing filtration.
Table 1a:
Initial blood flow rates and substitution fluid flow rates for 50kg and over

<table>
<thead>
<tr>
<th></th>
<th>50-59kg</th>
<th>60-69kg</th>
<th>70-79kg</th>
<th>80+kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INITIAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Substitution flow rate (ml/hr)</td>
<td>1900</td>
<td>2300</td>
<td>2600</td>
<td>3000</td>
</tr>
<tr>
<td>Blood flow rate (ml/min)</td>
<td>150</td>
<td>200</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td><strong>INITIAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% Ca Gluconate infusion rate (ml/hr)</td>
<td>12</td>
<td>15</td>
<td>18</td>
<td>21</td>
</tr>
</tbody>
</table>

Examples:

A 49kg child with a starting substitution fluid flow rate of 35ml/kg/hr (1715ml/hr) would have a BFR of 4ml/kg/min (196ml/min) and an initial Calcium Gluconate rate of 0.3ml/kg/hr (14.7ml/hr).

A 35kg child with a starting substitution fluid flow rate of 48ml/kg/hr (1680ml/hr) should have the BFR set at 5ml/kg/min (175ml/min) and the initial Calcium Gluconate infusion at 0.36ml/kg/hr (12.6ml/hr).

For a 4kg infant requires a starting BFR of 5ml/kg/min to achieve the minimum BFR of 20ml/min. To match this BFR the substitution flow rate should be 48ml/kg/hr and the Calcium Gluconate infusion rate 0.36ml/kg/hr, as per table 1.

A 3kg infant would have the BFR set at 20ml/hr (~7ml/kg/min) and the initial substitution fluid rate would be 63ml/kg/hr. The initial Ca Gluconate infusion rate will be set to 1.45ml/hr (~0.48ml/kg/hr).

A 75kg child will have a BFR of 200ml/min with a substitution fluid rate of 2600ml/hr, the initial Ca Gluconate infusion rate will be 18ml/hr as per Table 1a.
PERFORMING CVVH with CITRATE ANTICOAGULATION CONT.

Filtrate flow rate
This is determined by the substitution rate as the minimum movement of fluid across the filter membrane. Do not have less than 4 ml/kg/min blood flow and 35 ml/kg/hr substitution flow unless the blood flow is limited by access problems and can not be increased to this rate. In this case you need to decrease the substitution fluid rate to match the blood flow rate. (For example if only achieving blood flow rates of 3mls/kg/min then the substitution fluid rate must be changed to 27mls/kg/hr). This is not ideal as there is evidence from adult studies that show that 35ml/kg/hr filtration rate has a survival advantage over lower rates.

Fluid Balance
Net fluid balance for the PATIENT is the sum of ALL ingoing fluid minus ALL outgoing fluid.

Step 2
Calcium Infusion
- Plasma ionised calcium must be normalised prior to starting this treatment (>1.0mmol/L).
- Calcium Gluconate 10% contains 0.22mmol Calcium/ml. Give a bolus if necessary (0.5 ml/kg 10% Calcium Gluconate over 30 min)
- Infuse the undiluted 10% Calcium Gluconate via a central venous line (CVL). Where possible infuse via a dedicated lumen.
- Initial infusion rate is as per the table in Step 1.

Step 3
Monitoring and Adjusting the Circuit (Post-Filter) Ionised Calcium
- Circuit calcium must be measured to ensure effective anticoagulation.
- Using an arterial blood gas syringe, take blood samples for circuit plasma ionised calcium from the blue sample port in the return limb of the circuit (post-filter).
- Analyse it in the blood gas machine to determine the circuit ionised calcium level. Take a blood sample within 30 min of treatment, then after one hour, and 6-hourly thereafter. Adjust as necessary. REPEAT this sampling regimen whenever changes are made to the calcium infusion rate or the substitution fluid rate.
The circuit ionised calcium level should be between 0.25 and 0.50mmol/L. Adjust the substitution flow rate (and thereby the citrate flow rate), without adjusting the blood flow rate if the ionised calcium level is outside this range (Table 2). Do not go below 35ml/kg/hr of substitution fluid unless limited by blood flow rate.

A circuit ionised calcium less than 0.25mmol/L may be acceptable provided that the patient has an acceptable ionised calcium level, they are not receiving an excessive amount of calcium via infusion, and they are not developing a citrate gap. If there is an excess delivery of citrate at a substitution rate of 35ml/kg/hr you may need to replace some of the substitution fluid with non-citrate containing fluid (see notes at end). Sequential adjustments may be needed before stabilisation of the circuit ionised calcium.

Table 2:
Adjusting the citrate infusion rate (i.e. the substitution flow rate) on children less than 50kg

<table>
<thead>
<tr>
<th>Circuit ionised calcium (Ca)</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.25mmol/L</td>
<td>Decrease substitution rate by 10%</td>
<td>Do not adjust Blood flow rate</td>
</tr>
<tr>
<td>0.25-0.50mmol/L (Optimum)</td>
<td>No adjustment</td>
<td></td>
</tr>
<tr>
<td>&gt;0.5mmol/L</td>
<td>Increase substitution rate by 10%</td>
<td></td>
</tr>
</tbody>
</table>

Table 2a:
Adjusting the citrate infusion rate (i.e. the substitution flow rate) on children 50kg and over.

<table>
<thead>
<tr>
<th>Circuit ionised calcium (Ca)</th>
<th>Action</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.25mmol/L</td>
<td>Decrease substitution rate by 300ml/hr &amp; notify medical staff</td>
<td>Do not adjust Blood flow rate</td>
</tr>
<tr>
<td>0.25-0.50mmol/L (Optimum)</td>
<td>No adjustment</td>
<td></td>
</tr>
<tr>
<td>&gt;0.5mmol/L</td>
<td>Increase substitution rate by 300ml/hr &amp; notify medical staff</td>
<td></td>
</tr>
</tbody>
</table>
Step 4  
Monitoring and Adjusting the Systemic (Patient) Ionised Calcium

Arterial or venous blood gases from a separate arterial or venous line should be performed hourly initially to monitor the systemic ionised calcium. Ionised calcium must be kept in the range 0.9-1.2mmol/L. Adjust the separate Calcium Gluconate infusion according to Table 3. Sequential adjustments may be needed.

Table 3:  
Adjusting the calcium gluconate infusion rate on children **less than 50kg**

<table>
<thead>
<tr>
<th>Systemic ionised calcium (Ca)</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1.2</td>
<td>Decrease CaGluconate rate by 10%</td>
</tr>
<tr>
<td>1.0 - 1.2mmol/L (optimum)</td>
<td>No adjustment</td>
</tr>
<tr>
<td>0.8 - 0.99</td>
<td>Increase CaGluconate rate by 10%. Bolus CaGluconate if CVS unstable (see below)</td>
</tr>
<tr>
<td>&lt;0.8</td>
<td>Give 0.3ml/kg over 10 min and increase CaGluconate rate by 10%</td>
</tr>
</tbody>
</table>

Remeasure patient ionised Calcium 1 hour after making an infusion change.

Table 3a:  
Adjusting the calcium gluconate infusion rate on children **50kg and over**.

<table>
<thead>
<tr>
<th>Systemic ionised calcium (Ca)</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;1.4mmol/L</td>
<td>Decrease infusion by 4ml/hr and notify medical staff</td>
</tr>
<tr>
<td>1.2 – 1.4</td>
<td>Decrease infusion by 2ml/hr</td>
</tr>
<tr>
<td>1.0 – 1.2mmol/L (optimum)</td>
<td>No adjustment</td>
</tr>
<tr>
<td>0.8 – 0.99</td>
<td>Increase infusion by 2ml/hr</td>
</tr>
<tr>
<td>&lt;0.8</td>
<td>Increase infusion by 4ml/hr and notify medical staff</td>
</tr>
</tbody>
</table>

Remeasure patient ionised Calcium 1 hour after making an infusion change.

*If the Calcium infusion needs to be above 30ml/hr to maintain the patient’s ionised Calcium between 1.0 – 1.2mmol/L on the 50+ kg child then decrease the citrate based substitution fluid rate by 300ml/hr.

Recheck in an hour.

If the Calcium Gluconate infusion still needs to be above 20ml/hr to maintain the serum ionised Calcium consider changing to Accusol (HCO₃ buffered substitution fluid) and the Heparin anti-coagulation protocol.
EXTRACORPOREAL FILTRATION

PERFORMING CVVH with CITRATE ANTICOAGULATION CONT.

Record both the circuit ionised calcium and the patient’s ionised calcium on the filtration record sheet.

Sample patient ionised calcium hourly until stable. After 4 hours the hourly sampling rate may be decreased to 2 or 4 hourly if the ionised calcium is stable.

Step 5
Magnesium Replacement

- Plasma magnesium must be normalised prior to starting this treatment (>0.7 mmol/L).
  Give a bolus if necessary (0.2 mmol/kg MgSO₄ IV over 60 min).
- 50% Magnesium Sulphate (undiluted) 0.2 mmol/kg (0.1 ml/kg) should be given every 12 hours while citrate is running, via a separate central venous catheter (if a spare lumen is available) or into the venous return limb of the circuit. Do not mix it with calcium. This must be infused over at least 60 mins.
- The plasma magnesium should be measured 12hrly. If it falls to 0.7 mmol/L give an extra 0.2 mmol/kg of Magnesium Sulphate and decrease the interval between regular doses to 8 hours while the citrate is running.

The following Biochemistry requires immediate attention - Inform the PICU registrar or Consultant

- Ca⁺⁺ < 0.8 mmol/L or >1.4 mmol/L
- Total serum Ca > 3 mmol/L
- Na⁺ < 130 mmol/L or Na⁺ > 150 mmol/L
- HCO₃⁻ > 35 mmol/L
- pH < 7.25 or pH > 7.5
- Base Excess < - 5
- Patient Anion Gap > 8 mmol/L [Na⁺-(HCO₃⁻ + Cl⁻)]

Step 6
Changing the clearance (filtrate rate)

To improve clearance; increase the substitution flow rate (and therefore filtrate flow). This must be accompanied by a proportionate increase in blood flow, in order to keep the ratio between blood flow and citrate flow constant. (See table 1). This is a medical (intensivists) decision.
PERFORMING CVVH with CITRATE ANTICOAGULATION CONT.

If you change the prescription for the filtrate and blood flow (because you want a higher clearance, for example), then revert to hourly sampling until stable again.

Step 7
Other monitoring

Acid-Base

Citrate is completely metabolised in most patients with normal liver function.

A rising anion gap in a patient with a rising total calcium but a falling ionised calcium (despite increasing the Calcium Gluconate infusion) is caused by citrate accumulation (“citrate lock”). This is more likely in patients who have poor liver function and those receiving large amounts of blood products (these can contain large amounts of citrate). Acidaemia may also develop, with falling bicarbonate, an increasing anion gap, and a decreasing base excess. (Under normal circumstances the citrate in the circuit blood will cause an anion gap which is 5-7mmol/L greater than the patient’s anion gap. Therefore in assessing an anion gap it is important to do so on the patient’s blood not a circuit blood sample.)

Consider citrate lock if the total calcium is greater than 3mmol/L, the base excess is less than -5, or the anion gap is greater than 8mmol/L, particularly if the patient’s ionised calcium level is low despite an increasing calcium infusion rate.

Citrate lock can only be managed by decreasing the citrate infusion rate. REMEMBER that the substitution fluid rate should not be less than 35ml/kg/hr. If you need to decrease the citrate fluid rate to less than 35ml/kg/hr because of a developing citrate lock then replace SOME of the substitution fluid with either NaCl or NaHCO₃ containing fluids - depending upon the serum sodium and bicarbonate concentrations.

If replacing some of the substitution fluid with NaCl or NaHCO₃ remember to add it into the circuit pre-filter and include this volume in the ‘fluid loss total’ on the Aquarius as per Citrate Lock (step 8).

In some patients this situation continues to worsen and citrate anticoagulation may have to be abandoned and replaced by Heparin anticoagulation and bicarbonate (lactate free) replacement fluid.

Some patients with normal liver function may become alkalotic due to overproduction of bicarbonate from the citrate load. If this occurs use 0.45% or 0.9% Sodium Chloride as some of the replacement solution. This must be discussed with the Intensivist.

Electrolytes

Magnesium (total) should be checked 12 hourly. Sodium should be checked every 6-12 hours. Total Serum Calcium should be checked 12 hourly, and more frequently if more...
than two sequential increases in calcium Gluconate infusion rate have been required, or if a metabolic acidosis with rising anion gap occurs. See Acid/base section (above).

PERFORMING CVVH with CITRATE ANTICOAGULATION CONT.

Stopping CVVH with Citrate Anticoagulation

Cease the Calcium infusion immediately after ceasing citrate based substitution fluid. Recheck plasma total and ionised Calcium and total Magnesium at 1 hour and 6 hours post cessation.

**Step 8**

**Note**

- **Citrate Lock**
  
  If citrate lock is developing as evidenced by acidosis, increased anion gap, and increasing ratio of total:ionised calcium then you need to decrease citrate delivery.

  It is important that the substitution fluid rate is kept at not less than 35ml/kg/hr.

  To achieve this and not give excess citrate then some of the substitution fluid will need to be given as either Accusol 35 (if patient acidotic), 0.9% Sodium Chloride (if patient alkalotic and serum sodium normal), or 0.45% Sodium Chloride (if patient alkalotic and serum sodium high).

  This fluid may be given using the Aquarius scales BUT may have to be given and accounted for outside of the Aquarius fluid balance.

  If given separately add the new substitution fluid into the circuit pre-filter, at the ‘pigtail’ on the access line and add this volume into the ‘fluid loss rate (ml/hr)’ on the Aquarius.

  Start by replacing 1/3 of the citrate substitution fluid with one of the above fluids.

  This means that at the minimum substitution fluid rate of 35ml/hr the citrate substitution fluid will run at 20ml/kg/hr and the ‘new’ add-in substitution fluid will run via a separate IV pump at 15ml/kg/hr.
EXTRACORPOREAL FILTRATION

CRRT WITH HEPARIN

Setting up the Circuit using the Heparin based Anticoagulation Protocol

1 x Aquarius machine
1 x Aqualine set (<30kg = Aqualine S, >30kg = Aqualine)
1 x filter (<10kg = HF03, 10-30kg = HF07, >30kg = HF12)
1 x bag spike
3 x large bore 3-way taps and 3 x Smartsites (2x blue and 1x red)
2 x 1000ml 0.9% Sodium Chloride (priming fluid)
1 x Hotline tubing and Hotline unit
1 x 10ml syringe
Heparin infusion in 50ml BD Precise syringe (see pg 30)
ACT machine & LR cartridges
1 x 5l bag Accusol fluid (substitution fluid) + multi-bag spike (manifold) if hanging more than one bag of substitution fluid
(Remember extra U/F bags if hanging more than one bag of substitution fluid).

- Set up as per pages 7-9.
- Insert and prime Heparin line as per the Prepare Anti-coagulant screen on the Aquarius. Remember that the driver self-adjusts. Do NOT attempt this manually!
- Once connected the BFR is increased to run as fast as is tolerated by the patient. This is determined by the patient’s haemodynamic status and the circuit pressures. A guide to achievable BFR’s is available on page 5.
- Aim for replacement fluid rate (Accusol) of 35ml/kg/hr.
- Manage the Heparin infusion as per the Heparin protocol on page 28.
EXTRACORPOREAL FILTRATION

THERAPEUTIC PLASMA EXCHANGE
(Also known as Plasmafiltration)

Plasmafiltration is the process of filtering the patient’s blood via a continuous veno–venous extracorporeal circuit with a dedicated filter to remove the patient’s plasma and all its components, except for red blood cells, white blood cells and platelets. The patient’s plasma is then replaced with a combination of predominantly 4% Albumin and fresh frozen plasma (FFP).

The types of conditions that may require plasmafiltration in PICU are:

- Auto-immune disease, including;
  - Myasthenia Gravis
  - Idiopathic Thrombocytopenic Purpura (ITP)
  - Thrombotic Thrombocytopenic Purpura (TTP)
  - Glomerulonephritis

- Demyelinating polyneuropathies, including;
  - Guillian-Barré syndrome

- Connective tissue disease, including;
  - Systemic Lupus Erythematosus (SLE)

- Protein or plasma bound drugs

- Atypical Haemolytic Uremic Syndrome (HUS)

- SEPSIS

There is only a small pool of evidence for the appropriateness, efficacy and process of plasmafiltration.
Consultation with the appropriate specialty consultant is recommended if you are considering plasmafiltering a patient, as they hold the most current disease specific information and can probably recommend the optimal number of plasma volume exchanges and frequency.
THERAPEUTIC PLASMA EXCHANGE

TPE Anticoagulation

Patients undergoing extracorporeal techniques require anticoagulation to prevent the extracorporeal circuit from clotting. The usual anticoagulant for TPE is Heparin. See page 28 for the Heparin protocol.

In cases where there is a high risk of bleeding alternative means of anticoagulation may need to be utilised e.g. Heparin & Iloprost Protocol.

TPE Setup, Programming and Management

Set Up
1 x Aquarius machine
1 x Aqualine set
   <30kg = Aqualine S
   >30kg = Aqualine
1 x MPS 05 Plasmafilter
1 x bag spike
3 x large bore 3-way taps and 3 x Smartsites (2x blue and 1x red)
2 x 1000ml 0.9% Sodium Chloride
1 x in-line blood filter
1 x 500ml bottle of 4% Albumin & air inlet needle
1 x 50ml BD Precise syringe
Heparin (to make up infusion in 50ml syringe with 500 iu/kg in 0.9% Sodium Chloride)
Needle and syringe
(1 x Hotline tubing and Hotline unit)

ACT machine and LR cartridges

Instructions
- Turn on the Aquarius and await completion of self-test.
- If this is unsuccessful turn the Aquarius off.
- Ensure that all doors are closed and nothing is hanging on the scales. Turn back on to repeat the self-test.
- Select the TPE mode.
EXTRACORPOREAL FILTRATION

- Select the Paediatric (<30kg) or Adult (≥30kg) treatment.
- Make up Heparin infusion as per protocol (see page 28).

THERAPEUTIC PLASMA EXCHANGE CONT.

- Set up and prime as per machine directions.
- Ensure that the degassing chamber is firmly inserted with the hydrophobic filter line at the front of the unit and the line clamped until the substitution line is fluid filled. The ‘lid’ must be firmly in place.
- Ensure that the large bore 3-way taps and Smartsites are in-line (x2 on the return line and x1 on the access line, as per CRRT setup.)
- When plasmafiltering an infant/small child place the Hotline into the circuit between the return line and the 2x large bore 3-way taps to maintain thermoregulation.
- For stable children >10kg the circuit is 0.9% Sodium Chloride primed only with a direct ‘double connection’.
- For children <10kg or unstable re-prime the circuit with 4% Albumin prior to the direct ‘double connection’ connection OR utilise the Bypass Manoeuvre when connecting.
- Recirculate for 20+ minutes prior to connection.
- Immediately prior to connection hang the replacement fluid (usually 4% Albumin) and in-line blood filter on the substitution fluid side of the scale.

Programming

Ensure that a medical prescription has been written for the therapeutic plasma exchange.

One plasma volume exchange is 50ml/kg/hr.
Blood flow rate is 4ml/kg/min - minimum BFR 20ml/min, maximum BFR 200ml/min.
The number of exchanges per plasmafiltration session will be written by the PICU Consultant in terms of volume to be exchanged, replacement product(s) and timeframe. [It is usually 4/5ths 4% Albumin & 1/5th FFP.]

For example;

**On a 10kg child**
2 x plasma volume exchanges of 50ml/kg:
10kg x 50ml/kg = 500ml
» 500ml x 2 exchanges
= 1000ml over 4 – 6 hours

On the programming screen of the Aquarius;
- Select the **Fluid loss rate ml/hr** (4hrs = 250ml/hr, 6hrs = 170ml/hr)
  [the minimum fluid loss rate setting on the Aquarius is 100ml/hr]
EXTRACORPOREAL FILTRATION

- Dial up the **Total fluid loss ml** to achieve a goal of 1000ml.
- Enter the total weight of the replacement fluid containers (see next page).

**THERAPEUTIC PLASMA EXCHANGE CONT.**

The rate of exchange will be dictated by circuit and patient tolerance. Hence the variation in the timeframe.

In this example the replacement product will be proportioned as 800ml 4% Albumin (4/5th replacement volume), interspersed by one adult unit of FFP (1/5th replacement volume) - unless written otherwise by the PICU Consultant or indicated by patient.

At times you may also be required to administer cryoprecipitate (5ml/kg) if fibrinogen <1g/L.
Immunoglobulins (0.5gm/kg) may also be charted for administration.

**Documentation**

- Do not include the Heparin infusion and blood products that are infusing via the Aquarius pump in the ‘fluid in’ totals of the 24hr PICU Flowchart.
- As this is an exchange only modality there is no fluid loss total to transfer onto the 24hr PICU Flowchart.

**Dry Product Weights:**

4% Albumin bottle 500ml + in-line blood filter + air inlet = 320gm  
FFP bag (adult) = 33gm  
FFP bag (paediatric) = 16gm  
Cryoprecipitate container = 31gm  
Plasmafiltration trial bag = 84gm  
In-line blood filter = 17gm  
ELS bag spike = 2gm

Ensure that only Edwards Life Sciences spikes are used and that an air inlet is always inserted in Albumin bottle prior to attaching to circuit. If unequal emptying of Albumin bottles occurs – ensure air inlet is dry and/or insert another air inlet.
**EXTRACORPOREAL FILTRATION**

**CONNECTING**

**Double lumen connection**

**Required:**
- Sterile gloves (in appropriate size)
- Sterile guard
- Dressing pack with sterile gauze
- 2 x 10ml syringes
- 1 x 10ml vial of 0.9% sodium chloride
- 2% Chlorhexidine solution

If doing the bypass manoeuvre:
- 1 x adult unit red blood cells (RBC’s)
- 4 x 60 ml syringes
- 1 x in-line blood filter
- 1 x Cook Drainage bag adaptor – male luer lock
- 1 x urine drainage bag

Before attaching the circuit to the patient ensure that:
- baseline: FBC, coags, full U&E’s + an ABG have been obtained
- a PICU Consultant is present
- appropriate volume is present e.g. Red Blood Cells (as above)
- resuscitation sheet and drugs are available
- continuous ECG, SaO₂, BP and core temperature monitoring are in place.
- drug dosages to be reviewed by pharmacist
- the filtration orders have been written
Important:

If there is a Heparin lock in the catheter of a concentration greater than 10 iu/ml then it is essential that the Heparin is ASPIRATED out of the catheter lumens. If you are unable then medical staff must be notified.

- Using a sterile technique throughout the procedure clamp both lumens of the catheter.
- Clean the catheter hubs with the 2% Chlorhexidine solution and allow to dry.
- Using the 0.9% Sodium Chloride and 10ml syringes check that both the access (red) and return (blue) lumens aspirate and flush freely.
- If one lumen aspirates more easily then it will have the access (red) section of the circuit attached when connecting. If there is 1000 or 5000iu Heparin in the lumens you MUST aspirate and NEVER flush.
- Ensure the blood pump is stopped and clamp both ends of the extracorporeal circuit.
- Attach the end of the access line of the circuit to the red lumen of the catheter and the return end of the circuit to the blue lumen of the catheter, ensuring secure, bubble-free connections.
- Recheck the circuit for air bubbles, loose connections, cracks or deformities.
- Open all clamps on the blood path of the extracorporeal circuit.
- Start the blood pump slowly (30ml/min), watching for any sign of catheter obstruction or flow impedance.
- Gradually increase the blood pump speed until the circuit is thoroughly filled with the patient’s blood.
- Increase the flow to the required rate, ensuring that the patient’s blood pressure and heart rate and circuit pressures remain within acceptable parameters. Once the blood flow rate is at the prescribed rate or the maximum rate tolerated by circuit and patient, commence all infusions and the balance key at prescribed rates and ensure all lines unclamped. The circuit should be fully running within 15 minutes of connection.
EXTRACORPOREAL FILTRATION

- Ensure the Hot Line blood warmer is switched on.

CONNECTING CONT.

Bypass Manoeuvre

This is done when connecting any circuit onto a patient who weighs less than 10kg and/or is haemodynamically unstable.

- Draw up 4x 60 ml syringes of RBC’s via a blood filter.
- On the return line at the 3-way tap closest to the patient remove the Smartsite and attach one of the blood filled syringes. Turn the tap OFF to the circuit.
- At the 3-way tap most distal to the patient on the return line and turn the tap OFF to the patient, remove the Smartsite and connect the male luer lock and drainage bag. As the blood is being pulled from the patient infuse the red blood cells into the patient via the 3-way tap on the return line closest to the patient. The prime fluid from the circuit will drain off into the connected drainage bag.
- Continue to push RBC’s into the patient, gradually increasing the blood pump speed until the circuit is thoroughly filled with the patient’s blood.

This manoeuvre takes between 120 – 200ml of blood. Depending on patient stability and Hb you may chose to infuse more or less of the blood

- Once blood has completely filled the circuit turn the 3-way taps on the return line off to the drainage bag and 60ml syringe. Remove the syringe and drainage bag, replace the blue Smartsites.
- The RBC’s administered need to be documented. However they only count as volume administered if the volume of RBC’s given is greater than the volume of prime that is drained off.
RECYCLATING THE CRRT EXTRACORPOREAL CIRCUIT

May be required to temporarily disconnect circuit while transporting to CT/OR, etc.

1. Obtain a 100ml bag of 0.9% Sodium Chloride and two Edward LifeScience bag spikes (all in the Compactus).

2. Using an aseptic non-touch technique, swab the access and return ends of the circuit with 2% Chlorhexidine. Pause blood pump. Clamp each lumen. Disconnect access and return lines. Connect each lumen to a bag spike and spike the bag of 0.9% Sodium Chloride (100ml) – you will need to remove the injection bung to do this.

3. Follow the instructions as they appear on the Aquarius screen (operational screen/options/recirculating). This creates a “pretend” patient. The substitution fluid & filtration pumps will be stopped but the blood pump will circulate blood flow through the filter whilst the patient is off the machine.

4. If disconnecting for less than 30mins flush each catheter lumen with up to 5ml of Heparinised Saline (10u/ml). If disconnecting for greater than 30mins proceed as per disconnection (pg 30).

5. Inform medical staff.

6. Once each lumen is flushed cap with a sterile ‘blind end luer lock’ (Combi lock) and label clearly.

Please note there is no definitive ‘best’ method of recirculation or definitive evidence around maximum length of recirculation. We currently recommend no more than 2 hours of recirculation time.
DISCONNECTING CRRT/TPE CIRCUIT

This procedure reflects a planned disconnection from the patient and circuit.

1. Inform medical staff.
2. Stop the Aquarius blood and balance pumps (plus any circuit related infusions e.g. Calcium, Heparin).
3. Clamp access and return lines at catheter point closest to patient. For extra security, use GIZMO clamps.
4. At the catheter turn the 3-way taps OFF to patient.
5. Using an aseptic non-touch technique, swab the access and return ends of the circuit with 2% Chlorhexidine. Disconnect, including the 3-way taps.
6. Flush each lumen with 0.9% Sodium Chloride.
7. Fill each catheter lumen with Heparin 1000iu/ml to the volume stipulated on each lumen of the catheter.
8. Cap each lumen with a sterile ‘blind end luer lock’ (Combi lock).
9. Clearly document on each lumen, the drug, concentration, volume, time and write “DO NOT FLUSH”. Also document on PICU 24hr flowchart that the catheter is “Heplocked” with time and date.

10. THE CIRCUIT VOLUME IS NOT ROUTINELY RETURNED TO THE PATIENT WHEN A CIRCUIT IS DISCONTINUED.

11. Ensure the Heparin used for the heplocking is prescribed in the medication chart.
HEPARIN ANTI-COAGULATION

- Make up a Heparin infusion to 50mls total volume in a 50ml BD Precise syringe.
  
  Add Heparin 500iu x patient weight to 0.9% Sodium Chloride
  
  Thus 1ml/hr = 10iu/kg/hr.

- Utilise syringe driver on Aquarius (as per priming instructions)

- Adjust Heparin as per table overleaf to maintain ACT = 160 - 180.

- Take blood for ACT testing from the blue sample port (post filter) of the circuit.

- Keep platelet count greater than 50 x 10^9/L – correct with 10mls/kg as required.

  [ACT will be decreased with platelet transfusion. To maintain the ACT give a
  10iu/kg bolus of Heparin prior to commencing the platelets and increase the
  Heparin infusion rate by 10% while the platelets are infusing.]

- For an INR greater than 2 correct with FFP 10-20ml/kg.

- For a fibrinogen < 1g/L correct with cryoprecipitate 5ml/kg (usually a minimum of 1
  unit).

Consider limiting Heparin administration and boluses for patients with severe
coagulopathies such as fulminant liver failure and severe sepsis.

FFP and cryoprecipitate can also have variable effects on the ACT - so check the ACT
after they have been given.

Large falls in the platelet count may mean that HITT is occurring – check with a HITT
screen.

For the patients who bleed excessively while on the circuit, Prostacyclin and low dose
Heparin can be used (pg 30).

For those patients with an absolute contraindication to Heparin in whom citrate cannot be
used, an anticoagulant free circuit with the blood flow rate as high as is tolerated by the
circuit and patient is an acceptable means of managing the filter.

Consider an anti-coagulant–free circuit for patients with a severe non-correcting
coagulopathy (i.e. fulminant liver failure, severe sepsis).
HEPARIN ANTI-COAGULATION cont.

Table 1
Heparin Infusion Protocol

<table>
<thead>
<tr>
<th>ACT Range (sec)</th>
<th>Bolus (iu/kg)</th>
<th>Stop Infusion (min)</th>
<th>% Rate Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 100</td>
<td>50</td>
<td>0</td>
<td>+ 15%</td>
</tr>
<tr>
<td>100-120</td>
<td>30</td>
<td>0</td>
<td>+ 10%</td>
</tr>
<tr>
<td>120-140</td>
<td>10</td>
<td>0</td>
<td>+ 10%</td>
</tr>
<tr>
<td>140-160</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>160-180</td>
<td>0</td>
<td>0</td>
<td>- 10%</td>
</tr>
<tr>
<td>180-200</td>
<td>0</td>
<td>30</td>
<td>- 10%</td>
</tr>
<tr>
<td>&gt; 200</td>
<td>0</td>
<td>60</td>
<td>- 10%</td>
</tr>
</tbody>
</table>

- check ACT at 15, 30 and 60 minutes post commencement of the circuit.
- Make any changes necessary, as per table above.
- recheck ACT hourly and 30 minutes post any infusion bolus or change in rate.

WHEN USING HEPARIN AS THE ANTI-COAGULANT FOR HAEMOFILTRATION
USE ACCUSOL (PRE-DILUTION/PRE-FILTER) AS THE SUBSTITUTION FLUID.
PROSTACYCLIN (Iloprost) & HEPARIN ANTI-COAGULATION

Make up Heparin infusion as per Heparin Anti-coagulation. (See page 28.)

Make up Iloprost infusion (comes as 0.05mg = 50mcg in 0.5ml) using the following formulae:

Wgt < 16kg
Put 6mcg/kg in 50mls saline
Run at 1ml/hr = 2ng/kg/min via the ‘pigtail’ on the access line

Wgt >16kg
Put 100mcg in normal saline mls, the equivalent of 830 divided by the patient’s weight (kg). For example: if the patient weighs 30kg then put 100mcg in 830/30 = 27.7mls.
Run at 1ml/hr = 2ng/kg/min.

NB: Iloprost is a synthetic PGI₂ with approximately twice the activity and a more prolonged duration than normal PGI₂ (Epoprostenol).

Heparin and Iloprost are run at a fixed rate:
Heparin 1ml/hr = 10iu/kg/hr
Iloprost 1ml/hr = 2ng/kg/min

- This dose of heparin is unlikely to prolong the APTT or the ACT.
- Check APTT 6 hours after starting then daily if normal.
- If the Iloprost causes hypotension try decreasing the infusion to 1ng/kg/min.
- Keep platelet count > 100 x 10⁶/L.
- Correct INR and fibrinogen as required to keep in normal range.
- There is no need to monitor the ACT routinely if the APTT is normal.

Prostacyclin alone can be used if Heparin is contra-indicated.
It MUST infuse into the circuit PRE-filter.

WHEN USING ILOPROST &/OR HEPARIN AS THE ANTI-COAGULANT FOR HAEMOFILTRATION USE ACCUSOL (PRE-DILUTION/PRE-FILTER)
**EXTRACORPOREAL FILTRATION**

**AS THE SUBSTITUTION FLUID.**

**DEGASSING CHAMBER**

**Priming**

The Aquarius automatic degassing unit (ADU) starts working during priming mode. When the ADU pressure sensor detects less than -30mmHg (post-dilution pump is running) the ADU will automatically prime the degassing chamber (green diode switches from flashing to constant), AFTER 10 seconds FOR 10 seconds.

If the infra red sensor does not detect water after the initial prime, the pump will start again AFTER 2 minutes. For the second prime, the motor stops priming when liquid is detected at the infra-red sensor (second priming can not run more than 25 seconds).

If degassing line (with hydrophobic filter) is not connected to the pressure sensor, ADU status stays OFF (stand-by mode, green diode flashing).

*At the end of the priming mode the user has to check visually the fluid level inside the degassing chamber!*

**Functional Mode**

During functional mode, if the light beams don't detect fluid, the ADU will pump for a maximum of 3.5 seconds. If fluid is then detected it will pump from an additional 2 to a maximum of 3.5 seconds.

If fluid is not detected after 3.5 seconds of pumping, the pump will start again after 10 seconds. Waiting time during 2 consecutive pumping is always a minimum of 10 seconds.

If fluid is detected, pump will not start.

**Alarms and Controls**

Four different operation modes are indicated by the LEDs:

- **ADU self test:** ADU Red and Green LEDs are on
- **ADU self test failed:** ADU Red Led is flashing. Additional audible alarm
- **ADU Ready:** ADU Green LED is flashing
- **ADU Working mode:** ADU Green LED is permanently lit

The Aquarius degassing unit generates audible and visible alarms (ADU Red LED lit permanently) under the following condition:

- If the motor works for more than 25sec. Without detecting a filled chamber
- If the hydrophobic filter is blocked (measured pressure less than -300mmHg)
If the system detects a positive pressure higher than +30mmHg
If self test fails

In case of an alarm, eliminate the alarm cause. If the Aquarius degassing unit detects “normal conditions” (no blocked hydrophobic filter and a set level) the alarm is disabled. If the alarm is still active, the reset button has to be pressed.

The Aquarius Degassing unit resets automatically after 24 hours.

If the hydrophobic filter is disconnected from the pressure sensor (Pressure >-30mmHg) or if there is a leakage on the line, the pressure changes to 0mmHg and the ADU changes to stand-by mode (green flashing diode).

- If the hydrophobic filter gets wet then clamp and disconnect the filter line from the ADU and using a 10ml syringe flush air into the filter line to return the fluid to the degassing chamber. Disconnect the syringe, keeping the filter line clamped and allow the filter to air dry before re-attaching it to the ADU.
EXTRACORPOREAL FILTRATION

SUBSTITUTION FLUIDS
(stored in the Playroom in Room 1)

1. Edwards Life Science **Haemofiltration Solution Citrate 14mmol/litre**
   - 5 litres
   - **Citrate** based buffer substitution solution
   - Hang time 24 hrs
   - ALWAYS infuse pre-filter (predilution)

   Reconstitutes as:
   - Sodium 140mmol/L
   - Potassium 0mmol/L
   - Chloride 99mmol/L
   - Citrate 14mmol/L
   - Osmolality 254mOsm/L

2. Baxter **Accusol**
   - 5 litres
   - **Bicarbonate** based buffer substitution solution
   - Hang time = 24hrs
   - ALWAYS infuse pre filter (predilution)

   Reconstitutes as:
   - Sodium 140mmol/L
   - Calcium 1.75mmol/L
   - Magnesium 0.5mmol/L
   - Chloride 109.5mmol/L
   - Bicarbonate 33mmol/L
   - Osmolality 287mOsm/L
PREPARING an ACCUSOL BAG

Accusol:
Lactate free, bicarbonate base substitution fluid

Squeeze from edges at the seal between compartments A & B until the seal breaks. Mix well.

Remove Seal

Unscrew Cap

Connect Substitution Fluid Line
PREPARING an ACCUSOL BAG CONT.

Squeeze ‘wings’ until they snap flush with the access port – this causes the bag to be pierced.

Medication port – on rear of bag
POTENTIAL COMPLICATIONS OF CONTINUOUS RENAL REPLACEMENT THERAPY

Hypovolaemia
- Perform the bypass manoeuvre at the time of connection to reduce hypovolaemia, hypotension and/or systemic inflammatory response
- Have colloid readily available at beside for emergencies
- Manage fluid balance corrections by adjusting ultrafiltration rate only
- Monitor haemodynamics continuously

Fluid Overload
- Do not add extra fluid into circuit, unless in emergency
- Ensure that substitution fluid is as prescribed vs. delivery amount
- If substitution fluid pump stopped, address cautionary troubleshooting options on the screen
- Observe for signs of pulmonary oedema

Hypothermia
As the CRRT circuits are extra-corporeal, a fall in temperature of 0.5-1.0°C is expected.
- Continuously monitor core temperature
- Always set up and prime the circuit with an additional blood warmer set in situ, however it may not always be necessary to use during therapy as long as the patient’s temperature is maintained
- Use the Bair Hugger to warm the patient if core temperature is less than 36.0°C
- If substitution pump stopping continually for high temperatures – consider the blood warmer if not already in-line.

Infection
- Avoid contamination of the exposed ends of sterile equipment when priming the circuit
- Avoid breaking the circuit wherever possible
- Redress cannula site 48 hourly/prn and record on the procedures chart
- Monitor central temperature and observe cannulation site for inflammation
- Manage venous catheter in accordance with central line RBP
EXTRACORPOREAL FILTRATION

DOCUMENTATION

- Use a new Filtration Record for every 24hr period (0800-0700)

- All orders, interventions and trouble shooting are to be documented on the Filtration Record sheet.

- At the end of a ‘CRRT’ duty enter a shift summary into the clinical notes.

- Orders are to be written daily by Medical staff on the Filtration Record.

- Only the Fluid Loss (ml/hr) is transcribed from the Filtration Record sheet to the PICU 24hr Flowchart.
<table>
<thead>
<tr>
<th>Time</th>
<th>Blood Flow Rate (mL/min)</th>
<th>Substitution Fluid (mL/hr)</th>
<th>Circuit I/O</th>
<th>Action</th>
<th>Comments</th>
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</thead>
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<td>119</td>
<td>159</td>
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<td>Serum Ca = 2.95</td>
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<td>cT</td>
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</tbody>
</table>

**Filtration Prescription & Record – CVVH**

**Patient Name:**

**Weight:** 45kg

**Substitution Fluid:** ELS cation based fluid

**Substitution Fluid Rate:** 1820mL/hr (48mL/kg/hr)

**Additional to Substitution Fluid:**
- 1L of 3% Dextrose per 6 hours
- 0.9% NaCl per 6 hours

**Bypass Manserette:** Yes

**Hourly Fluid Balance Target:** 130mL

**Signature:** 

---

**Filtration Prescription & Record – CVVH Cont.**

---
## Extracorporeal Filtration

**Filtration Prescription and Record**

**Date & Time** | **Orders and Interventions** | **Signature**
--- | --- | ---
03/12/07 0930hrs | Change from citrate to heparin anticoagulation - ACT 140-160 | B.M.
Prefilter 200u/kg in 50ml saline
20,000u in 50ml saline @ 1-10ml/h
Replacement Hemosol (- 20ml/kg/1.5L)

If there is no room in the comments space then troubleshooting and/or interventions can be written here too.

Remember to write a circuit shift summary in the clinical notes.

<table>
<thead>
<tr>
<th>Time</th>
<th>Type of Substitution Fluid</th>
<th>KCL in mmol added to each 5L Bag</th>
<th>K+HCO3 in mmol added to each 5L Bag</th>
<th>Number of 5L Bags</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>1700hrs</td>
<td>Hemosol</td>
<td>15mmol</td>
<td>-</td>
<td>1</td>
<td>SMJP</td>
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**Checklist**

<table>
<thead>
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<th>07:00-1830</th>
<th>1800-07:30</th>
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<tbody>
<tr>
<td>Treatment Mode</td>
<td>CVWH</td>
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<tr>
<td>Filter type and size</td>
<td>HP12</td>
</tr>
<tr>
<td>Blood flow rate</td>
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<tr>
<td>Substitution fluid type</td>
<td>Citrate</td>
</tr>
<tr>
<td>Substitution fluid rate (ml/kg/h)</td>
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<tr>
<td>Calcium Gluconate-Heparin/Epoprostenol infusion(s) correctly made up and infusing</td>
<td>Yes</td>
</tr>
<tr>
<td>Hourly fluid balance target prescribed</td>
<td>Yes</td>
</tr>
<tr>
<td>Catheter (size, site, date inserted)</td>
<td>11FR, L Fem, 2/12/07</td>
</tr>
<tr>
<td>All connectors tight</td>
<td>Yes</td>
</tr>
<tr>
<td>Circuit commenced (date and time)</td>
<td>02/12/07 @ 1200hrs</td>
</tr>
<tr>
<td>Gizmo clamps available in bedside</td>
<td>Yes</td>
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</table>

Signature: [Signature]
Date & Time: [Date & Time]
## Extracorporeal Filtration

**Filtration Prescription and Record**

-Fil balance on the FIL 24 hour flowchart must be done hourly and promptly-

### Patient Details
- **Name:**
- **Weight:** 45kg
- **Substitution Fluid:** 4% albumin & PFP
- **Anticoagulation:**
  - CVL + Heparin
  - CVL + Heparin & Iopamidol
  - TPE + Heparin
- **Bypass Manoeuvre:** Yes
- **Hourly Fluid Balance Target:** 4500ml

### Filtration Details

- **Blood Flow Rate:** 50-100
- **Substitution Fluid Rate:** 870ml/hr x 3
- **Add to Substitution Fluid:** K+ concentration in substitution fluid = 2.2mmol/L

### Filtration Flow Chart

<table>
<thead>
<tr>
<th>Time</th>
<th>Blood Flow Rate (mL/min)</th>
<th>Substitution Fluid (mL/hr)</th>
<th>Fluid Loss (mL/hr)</th>
<th>Circuit Ca (bind)</th>
<th>PT (%)</th>
<th>APTT (%)</th>
<th>Comments</th>
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</thead>
<tbody>
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</tbody>
</table>

### Comments
- **TPE completed**

### Circuit Details
- **Pressure Settings:**
  - MAP: 60
  - CI: 4L
  - HR: 60

### Circuit Notes
- **Small clot & one of filter opened**

---

**Filtration Prescription & Record – TPE Cont.**

---

**Legend:**
- TPE: Therapeutic Apheresis Procedure
- CVL: Central Venous Line
**EXTRACORPOREAL FILTRATION**

**Filtration Prescription and Record**

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Orders and Interventions</th>
<th>Signature</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/08/27 @ 0800</td>
<td>Plasma 2 x volume exchange (50ml/kg x2) over 6' (562.5ml/hr x 6 = 4500)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.1 albumin: FFP - depending on tally, FFP 1x</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If there is no room in the comments space then troubleshooting and/or interventions can be written here too</td>
<td></td>
</tr>
</tbody>
</table>

Remember to write a circuit shift summary in the clinical notes.

<table>
<thead>
<tr>
<th>Time</th>
<th>Type of Substitution Fluid</th>
<th>KCL in mmol added to each 5L Bag</th>
<th>K+Hos in mmol added to each 3L Bag</th>
<th>Number of 3L Bags</th>
<th>Sig</th>
</tr>
</thead>
</table>

Record: FFP & 4% albumin bags that are administered via the circuit in this space.

**Checklist**

<table>
<thead>
<tr>
<th></th>
<th>07:00-16:00</th>
<th>16:00-27:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Mode</td>
<td>TPE</td>
<td></td>
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<tr>
<td>Filter type and size</td>
<td>MFD965</td>
<td></td>
</tr>
<tr>
<td>Blood flow rate</td>
<td>1000ml/hr</td>
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<tr>
<td>Substitution fluid type</td>
<td>ALB 4%: FFP</td>
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</tr>
<tr>
<td>Substitution fluid rate (mL/kg/hr)</td>
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<td></td>
</tr>
<tr>
<td>Calcium Gluconate-Heparin (top up infusion)</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Hourly fluid balance (tare + prescribed)</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Catheter (size, site, data inserted)</td>
<td>11.5Fr, 15cm, 8LJ, 2009</td>
<td></td>
</tr>
<tr>
<td>All connectors tight</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Circuit committed (date and time)</td>
<td>20/08/07 @ 0900</td>
<td></td>
</tr>
<tr>
<td>Glucose clamps available in bedside</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>

Signature: [Signature]

Date & Time: 20/08/07 @ 0800hrs