

**Crumlin | Temple Street | Tallaght | Connolly**

**Childrens Health Ireland Nursing Practice Guideline on**

**Therapeutic Plasma Exchange (TPE)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Area of use:** | All of organisation [ ]  | CHI at Connolly [ ]  | CHI at Crumlin [ ]  |
|  | CHI at Tallaght [ ]  | CHI at Temple Street [x]  |
| **Lead author** **& title:** | Yvonne O’Reilly TPE Clinical Nurse Manager IIClaire Mc Cabe Haemodialysis Clinical Nurse specialist  |
| **Approved by** **& title:** | Dr Michael Riordan, Consultant Paediatric NephrologistProfessor Kevin CarsonConsultant in Paediatric Intensive Care Medicine |
|  | Nursing Documentation Approval Committee Nov 2023 |
| **Version:** | 2 | **Approval date:** | November 2023 |
| **Reference:** | CHINPGTPE-YORCMCC—11-2023 | **Revision due:** | November 2026 |
| **Version History** |
| **Version:** | **Date approved:** | **Summary of changes:** | **Author:** |
|  |  |  |  |
| 1 | 2018 | Routine Review | Maria Raftery, Clinical Nurse Manager II |
|  |  |  |  |

Contents

[1.0 Guideline statement 4](#_Toc140056806)

[2.0 Scope 4](#_Toc140056807)

[3.0 Introduction to Therapeutic Plasma Exchange 4](#_Toc140056808)

4.0 [Glossary of acronyms, terms and definitions 5](#_Toc140056809)

[5.0 The Aquarius Machine 5](#_Toc140056810)

[6.0 Clinical Indications for Plasma Exchange 5](#_Toc140056811)

[7.0 Referral Process 6](#_Toc140056812)

[8.0 Procedures 6](#_Toc140056813)

 8.1 [Vascular Access 6](#_Toc140056814)

 8.2 [Lines 7](#_Toc140056815)

9.0 [Filters 7](#_Toc140056816)

 [9.1 Plasma Volume 8](#_Toc140056817)

 9.2 [Duration of Session 8](#_Toc140056818)

 9.3 [Blood Flow Rate 9](#_Toc140056819)

 9.4 [Replacement Fluids 9](#_Toc140056820)

[10.0 Anticoagulation for Plasma Exchange: Heparin 9](#_Toc140056821)

 10.1 [Dosage of Heparin 10](#_Toc140056822)

 10.2 [Heparin Infusion 10](#_Toc140056823)

 10.3 [Heparin Bolus during treatment 10](#_Toc140056824)

 10.4 [Contraindications of Heparin 11](#_Toc140056825)

 [10.5 Lining and Priming the Aquarius Machine 11](#_Toc140056826)

11.0 [Programming the Aquarius Machine 12](#_Toc140056827)

 11.1 [Connecting and disconnecting Procedure 12](#_Toc140056828)

 11.2 [Transmembrane Pressure (TMP) in Filter 13](#_Toc140056829)

 [11.3 Emergency Management 14](#_Toc140056830)

 11.4 [Complications 15](#_Toc140056831)

[5.0 Monitoring, audit and evaluation 16](#_Toc140056832)

[6.0 Key stakeholders 16](#_Toc140056833)

[7.0 Communication and training 16](#_Toc140056834)

[8.0 References 16](#_Toc140056835)

[9.0 Appendices 18](#_Toc140056836)

[Appendix 1 **PLASMA EXCHANGE ALGORITHM** 18](#_Toc140056837)

[Appendix 2 Central Venous Access |Device Data 19](#_Toc140056838)

[Appendix 3 20](#_Toc140056839)

[Appendix 4 Trouble Shooting 20](#_Toc140056840)

# Policy statement

The purpose of this document is to provide clinical guidance for the safe management of children requiring plasma exchange. It will equip nursing staff with the knowledge required to deliver specialised, high quality and evidence-based care for all paediatric patients receiving plasma exchange with the Aquarius Machine.

# Scope

This guideline is applicable to nursing staff deemed competent in the provision of Therapeutic Plasma Exchange and management of CVAD’s within the Nephrology Department and PICU. It is pertinent to all medical and nursing staff that coordinates the referral and management of all paediatric patients requiring plasma exchange, to include both the prescription and delivery of the therapy.

# Introduction to Therapeutic Plasma Exchange

Therapeutic Plasma Exchange (TPE) is an extracorporeal apheresis treatment in which a person’s plasma is removed from the cellular components of the blood (see diagram 1) and substituted concurrently with crystalloid and colloid solutions, such as albumin or octoplas (Joseph et al. 2021). The purpose of this procedure is to eliminate and deplete pathologic substances from the blood that may be contributing to the patient’s underlying disease. These pathogenic molecules include antibodies, toxins, cytokines, and immune complexes (Kaplan 2013). The basic premise of TPE is that removal of these aggravating agents will reduce clinical symptoms and progression of the disease, and in some instances, it may permit reversal of the pathogenic activity (Bobati and Naik 2017). TPE is also used to replenish a deficient factor or plasma component such as factor H in atypical haemolytic uraemic syndrome (Carter and Benador 2014).



**Diagram 1:** Schematic section of a hollow fibre for plasma exchange

(Ahmed and Kaplan 2020)

# 4.0 Glossary of acronyms, terms and definitions

ACT Activated clotting time

ABG Arterial Blood Gas

ASFA American Society for Apheresis

BSA Body surface area

CVAD Central venous access device

CVC Central venous catheter

ECV Extracorporeal volume

FFP Fresh frozen plasma

HUS Haemolytic ureamic syndrome

PICU Intensive Care Unit

MDRO Multi Drug Resistant Organism

TBV Total blood volume

TPE Therapeutic Plasma Exchange

VBG Venous blood gas

# 5.0 The Aquarius Machine

The Aquarius system is an automated fluid balance monitor, designed to be used with various extracorporeal treatments in the field of renal replacement therapies or plasma therapies.

The system contains three circuits: the extracorporeal circuit, the substitution circuit, and the filtrate circuit.

The plasma exchange is controlled and balanced by the substitution pump, filtrate pump and the scales.

Blood is passed along a highly porous membrane, the plasma filter, and filters the blood allowing the plasma to pass across. The transmembrane pressure (TMP) forces the plasma through the filter membrane, while larger cells and platelets remain in the blood path (Carter and Benador 2014). The membrane allows the clearance of molecules under a certain size (approximately 3 million Daltons in weight) but prevents the passage of blood cells (erythrocytes, leucocytes, and platelets) as they are larger. Blood is continuously pumped out of the body around a circuit, where the plasma is removed, and replacement fluid is infused before being pumped back into the body for the duration of therapy.

See Appendix 4 for troubleshooting guide such as a Blood Leak Alarm, when using the Aquarius Machine.

# 6.0 Clinical Indications for Plasma Exchange

The American Society for Apheresis (ASFA) provides an exhaustive list of evidence-based recommendations on indications for TPE. Outlined below are some common conditions for which TPE is applied.

**Renal**

* Focal Segmental Glomerular Sclerosis (FSGS) – TPE is utilised both pre-emptively before organ donation and to manage recurrence post-transplant
* Antineutrophil Cytoplasmic Antibody (ANCA) – associated Rapidly Progressive Glomerulonephritis
* Haemolytic Uraemic Syndrome (HUS) – Typical and Atypical
* Vasculitis
* Good Pastures Syndrome

**Neurology**

* Renal Allograft dysfunction and rejection
* Guillain-Barre Syndrome
* Myasthenia Gravis
* Acute Disseminated Encephalomyelitis
* Transverse Myelitis
* Anti N-methyl D-aspartate (NMDA) Receptor Encephalitis
* Optic Neuritis

**Haematology** – Thrombotic Thrombocytopenic Purpura

# 7.0 Referral Process

The Plasma Exchange Algorithm (Appendix 1) directs the provision of TPE within CHI at Temple Street. This includes referrals from outside of CHI. TPE is provided exclusively by the TPE CNM II, trained nephrology nurses in the Haemodialysis Department/St. Michael’s C renal ward or by nurses in the Paediatric Intensive Care Unit. All candidates for plasma exchange must be discussed with the relevant physicians:

Paediatric Consultant Nephrologist Dr Michael Riordan is the clinical medical lead for plasma exchange within the renal department

Consultant Intensivists authorise Plasma Exchange treatments in the PICU setting.

#  Procedures

# 8.1 Vascular Access

Membrane-based TPE as performed with the Aquarius Machine necessitates a high blood flow rate due to the propulsion of blood through the plasma filter. The establishment of secure, central vascular access with optimum blood flow is critical to a successful and effective plasma exchange therapy (Ipe and Marques 2018). A dual-lumen catheter is sited, most commonly, in the internal jugular or femoral vein to obtain adequate access for treatment (**Appendix 2)**.

* In the PICU setting a ‘vascath’, a non-cuffed and non-tunnelled catheter, is usually placed percutaneously using ultrasound guidance and a Seldinger Technique to facilitate TPE.
* In the Nephrology Department, with consideration of the potential for a longer duration of treatment and patient factors that may affect line security, a cuffed and tunnelled dual lumen permcath should be inserted unless otherwise directed by a consultant.

**Extracorporeal Volume**

* Total blood volume (TBV) is calculated as 80mls per kilogram of body weight
* The extracorporeal volume (ECV) is calculated as 8-10% of the child’s total blood volume. The total amount of extracorporeal blood should not exceed 10% of the patient’s total blood volume to avoid hypotension and haemodynamic instability (American Nephrology Nurses Association 2021)

**8% of TBV** = weight (kg) x 80 (mls) x 8 / 100 **or body weight x 6.4 (mls)**

**10% of TBV** = weight (kg) x 80 (mls) x 10 / 100 **or body weight x 8 (mls)**

Once the ECV is calculated, it can be used to ascertain the most suitable combination of filter and lines as the plasma exchange circuit needs to be customised to the size of the patient (Cortina et al. 2018).

# 8.2 Lines

There are 2 types of lines available for plasma exchange:

|  |  |
| --- | --- |
| Aqualine S (Paediatric Set) | Priming volume 64mls |
| Aqualine (Adult Set) | Priming volume 105mls |

# 9.0 Filters

Filter surface area should be equal to or less than that of the child’s body surface area (British Association for Paediatric Nephrology 2008).

Note the priming volume of the selected filter when developing the child’s TPE circuit. See below table for available filters with corresponding surface areas

|  |  |  |  |
| --- | --- | --- | --- |
| **Model** | **Microplas****MPS03** | **Microplas****MPS05** | **Microplas****MPS07** |
| **Surface Area M²** | 0.30 | 0.45 | 0.68 |
| **Blood compartment ml** | 30 | 50 | 70 |

**N.B Please ensure that all Plasma filters are checked by two nurses. The filters must be clearly labelled for plasma separation and must not be used in continuous therapies such as CVVH.**

Priming volume of filter and bloodline set should not exceed the ECV.

Consider a blood or albumin circuit prime if the patient’s weight ≤ 10Kg or if ECV exceeds the required circuit priming volume (Heeyeon 2020).

See below table for further information on choosing Filter / Lines and Priming Volumes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Body Weight****(Kgs)** | **Tubing****Set** | **Lines****Priming Volume** | **Filter****Surface Area** | **Filter****Priming Volume** | **Total Circuit****Volume** |
| 0 to 5 kgs | Aqualine S | 64mls | MPS03- 0.30M2 | 30mls | 94mls |
| 5 to 15kgs | Aqualine S | 64mls | MPS03- 0.30M2 | 30mls | 94mls |
| 16 to 40kgs | Aqualine S | 64mls | MPS05- 0.45M2 | 50mls | 114mls |
| 40 - 60kgs | Aqualine or Aqualine S | 64-105mls | MPS05- 0.45M2 | 50mls | 114- 165mls |
| > 60kgs | Aqualine  | 105mls | MPS07- 0.68M2 | 70mls | 175mls |

## **9.1 Plasma Volume**

The cellular elements of a person’s blood (erythrocytes, leucocytes, and platelets) are suspended in the liquid plasma. Plasma is 91.5% water, in which are suspended proteins, hormones, enzymes, gases, electrolytes and metabolites.The patient’s plasma volume must be determined when formulating a TPE prescription:

* Calculate the patients TBV (80mls/kg)
* Plasma volume is calculated as 40mls per kg of body weight (Nickson 2020)
* The first exchange is usually only one plasma volume

= 40mls per kilogram of body weight

* Standard practice is 1.0-1.5 plasma volumes exchanged each session

= 40-60mls per kilogram of body weight (Alhasan 2019)

* With consultant direction only, up to 2 plasma volumes can be exchanged each session = 80mls per kilogram of body weight (Eyre et al. 2018)
* Maximum total exchange volume is 3 litres.

**Discuss individual patient prescription with Consultant Nephrologist/ Intensivist.**

## **9.2 Duration of Session**

* For most conditions in which TPE is used, it is considered acceptable to perform 1 to 1.5 plasma volume exchanges per procedure. One volume plasma exchange removes approximately 66% of an intravascular disease mediator when there is no new synthesis or redistribution of the factor (Norfolk 2013). A 1.5 plasma volume exchange can yield up to 72% removal of the original pathogenic factors circulating in the plasma (Carter and Benador 2014).
* On occasion, a 2 plasma volume exchange may be required if specifically requested by medical team.
* As circulating disease mediator will rise following treatment, typically an initial course of up to 5 daily consecutive plasma exchange sessions is performed. The number & frequency of exchanges is influenced by the type of disease, clinical status, and response (Eyre et al 2018).
* First plasma exchange session is always at least 3 hours duration to avoid complications and should be limited to a single plasma volume exchange only (Eyre at al 2018).
* Performing more than one plasma volume exchange increases procedure time.
* Sessions take approximately 2-3 hours once stable, but the length of time depends on the volume of plasma to be exchanged and how well the patient tolerates the procedure.
* Discuss length of therapy time with Consultant Nephrologist/ Intensivist when devising the prescription.
* If daily sessions are required, please note sessions do not have to be 24 hours or greater apart please discuss intervals between sessions with Consultant Nephrologist/Intensivist.

## **9.3 Blood Flow Rate**

* Blood flow rate should never exceed Extra Corporeal Volume (8-10% of patients Total Blood Volume).
* Blood flow speed for Aqualine S (paediatric set) is 10 to 200mls / min
* Blood flow speed for Aqualine (Adult set) is 30 to 250mls / min.
* Always commence treatment at a reduced blood flow and increase rate once patient is stable on machine.

|  |  |  |
| --- | --- | --- |
| **Blood Pump Speed (BPS) (8-10% of TBV)** |  |  |
| **Weight of Child** | **Initial Pump Speed** | **Suggested Pump Speed** |
| 0 - 5kgs | 10mls / min | 10 - 30mls / min |
| 1. - 10kgs
 | 20mls / min | 30 - 40mls / min |
| 10 - 25kgs | 40mls / min  | 50 - 120mls / min |
| 25-40kgs  | 60mls / min | 120 - 160mls / min |
| Over 40kgs | 100mls / min | 160 - 250mls / min |

##  **9.4 Replacement Fluids**

* When plasma is removed, a replacement fluid is infused ml per ml. The fluid removed by TPE must be replaced to prevent marked volume depletion and maintain oncotic pressure.
* The replacement fluid is usually a combination of 60-80% colloid and 20-40% crystalloid. The infusion of the crystalloid and colloid solutions is alternated but most of the colloid should be given towards the end of the procedure to avoid hypovolaemia (Winters 2012).
* The combination of replacement fluid varies with the patient’s clinical presentation– please discuss replacement fluids with prescribing consultant (Winters 2012). Choice of replacement fluids is consultant led and may differ in ICU and Nephrology settings.
* **5% Albumin solutions** have the advantage of lack of viral transmission and minimal risk of anaphylactic reactions. 5% Albumin only exchanges can cause depletion in clotting factors (fibrinogen and antithrombin III) and may predispose to bleeding, and a loss of immunoglobulins. To counteract this, at least every 4th - 5th session should be with plasma (i.e., Octaplas / Uniplas). However with consideration to the patient’s clinical status and consultant decision, octaplas can be administered from the first session if required. Octaplas is virally inactivated FFP, and it contains the coagulation factors that are absent in albumin solutions.
* For patients with coagulopathy the colloid component of the replacement fluids administered is usually Octaplas / Uniplas. There is an increased risk of hypocalcaemia with octaplas. Ionised calcium must be monitored closely and administer I.V. calcium gluconate if ionised calcium is ≤ 1mmol/l. If using Octaplas as replacement fluid it is important to note that it should be administered at the end of the session as administering plasma at the start of TPE will result in some of it being subsequently removed by the treatment, resulting in patient exposure to blood products without the benefit (Winters, 2012).

# 10.0 Anticoagulation for Plasma Exchange: Heparin

* The aim of anti-coagulation is to maintain efficacy of the extracorporeal circuit during plasma exchange, prevent clotting of the filter, blood lines and vascular access without causing bleeding complications to the patient.
* Anticoagulant of choice is Heparin sodium (un-fractionated heparin) and is infused pre-filter.
* Heparin initiates anticoagulation rapidly but has a short duration of action. For children at high risk of bleeding, heparin is suitable because its effect can be terminated rapidly by stopping the infusion
* A heparin infusion is maintained throughout the treatment

##

## **10.1 Dosage of Heparin**

A heparin bolus is given through the Smart Pump and into the circuit as soon as the blood hits the filter.

Consult with the relevant Nephrologist or Intensivist if bolus is to be given

##

## **10.2 Heparin Infusion**

* Use Standard Concentration Formula using Smart Pump. Ensure Care Unit on the pump is CVVH. Enter weight band as requested and select CVVH Heparin.
* Connect infusion to Aqualine/Aqualine S set prior to connection.
* Commence infusion as prescribed (units/kg/hr) and titrate according to Activated Clotting Time (ACT) results (Table 2).
* Activated Clotting time should be monitored and recorded every 30minutes minimum with the sample drawn from the blue port of the TPE circuit
* The patient may require 10 - 30 units per kg per hour. **Maximum of 35 units per kg in ICU setting. Maximum of 50 units per kg for some Nephrology patients at ward level as directed by Consultant.**
* Administer heparin as per parameters set by consultant Nephrologist/ Intensivist. The standard target range for ACT is 180-220seconds (Carter and Benador 2014)
* If the patient is actively bleeding or has a severe coagulopathy, consider lower ACT parameters or heparin free plasma exchange sessions – discuss with consultant.

|  |  |
| --- | --- |
| **PICU Standard concentration infusion drug library**Please refer to below table for guidance on standard concentration infusion drug library and weight bands (Paed SCI Library Version 4, 2019). | **Rate calc ml/hr = Required dose × default rate (ml/hr)****Default start dose** |
| **Drug**  | **Weight Band**  | **SCI (normal)** | **Diluent** | **Usual Dose Range**  | **Default Start Dose** | **Default Rate mls/hr** |
| CVVH HEPARIN (in own care unit on pumps | ≤2.5 kgs | 1000 units/50mls | Glucose5% w/vOr Nacl 0.9% w/v | 5-20 units/kg/hr | 10 units/kg/hr | 0.5×wt |
| >2.5 - ≤10 kg | 2500 units/50mls | 0.2×wt |
| >10 -≤ 20kg | 5000 units/50mls | 0.1×wt |
| >20kg  | 10000 units/50mls | 0.05×wt  |

## **10.3 Heparin Bolus during treatment**

A bolus of heparin may be required during plasma exchange therapy if ACT levels are low. A bolus can be given in increments of 5 international units/kg or 10 international units/kg. This may help prevent any further reduction in ACT and formation of a clot. ACT parameters should be set for each session prior to commencing therapy.

 See table 2 below for guidance

|  |  |
| --- | --- |
| **ACT Level (seconds)** | **Heparin** |
| Greater than 220 | Decrease infusion by 5units / kg /hr. |
| 180 – 220 | No change in heparin infusion |
| 150- 180 | Increase heparin infusion by 5units / kg / hr. |
| Less than 150 | Administer heparin bolus (10units/ kg) and increase heparin infusion by 5units / kg / hr. **Repeat ACT after 15 minutes.** |

## **10.4 Contraindications of Heparin**

Heparin should be used with caution and / or withheld according to prescribing consultant in the following circumstances:

* Imminent or recent surgery
* Disseminated intravascular coagulation
* Heparin induced thrombocytopenia
* Coagulopathies such as thrombocytopenia
* Liver disease
* Haemophilia
* High urea levels > 35mmols- increased risk of bleeding - **reduced dose required**.

## **10.5 Lining and Priming the Aquarius Machine**

***Equipment Needed***

* Aqualine S (Paediatric) or Aqualine (adult) tubing set as per prescription.
* Microplas Filter (size as per prescription)
* 1000 mls bags of NaCl 0.9% x 2
* 3-way manifold set x 1
* Blood filters x 2-3 (Sangofix B blood administration set)
* Heparin Infusion as prescribed

Refer to Aquarius Manual for step-by-step guide to lining and priming machine. Always ensure machine is turned on and correct TPE is selected prior to lining machine.

***Note***:

* Ensure that there is a static green and amber light on the top of the machine prior to lining.
* Ensure that the heater coil is inserted first into the side of the machine to avoid CPU heater error in priming mode.

***Priming***

* Attach blood filters (only required for octaplas) to 3-way manifold set which is to be attached to substitution fluid scale.
* Prime machine with 1litre of Normal Saline 0.9%.
* Re-circulate lines pre commencement of session. As per company recommendations recirculation is required 30 minutes prior to connection with the MPSO3 and MPSO5 and 45-60 minutes with MPSO7 to allow all pores in filter to become saturated and aid stable TMP. Increase blood flow rate from default 10ml/min to at least 100ml/min to ensure full saturation of filter.
* If patient is ≤ 10kgs, discuss necessity/ possibility of priming circuit with 5% albumin or blood with Consultant Nephrologist or Intensivist.

## **11.0 Programming the Aquarius Machine**

The programming function can be activated at any point after priming is completed. Machine should be programmed prior to patient connection. When programming machine, please enter:

* Time will be determined by the total volume set so this section can be bypassed.
* Total amount to be exchanged as per prescription
* Rate of exchange i.e., plasma volume to be exchanged per hour.
* Weight - Please consider the dry container weights of all replacement fluids required for the patient when programming the weight on the machine:

|  |  |
| --- | --- |
| **Replacement Fluid** | **Dry Weight of Container / Bag** |
| 1000mls 0.9% Nacl | 25g |
| Octaplas (200g) | 15g |
| Albumin 5% 250ml  | 125g |
| Albumin 5% 500ml | 250g |

* It is recommended that all bag/bottles of replacement fluids should be put on the scales in addition to the 0.9% Normal saline 1000mls
* If this is not possible only the dry weight of the bottles hanging on the scales should be programmed.
* Do not programme heparin rate ( this will be administered via smart-pump)
* Temperature setting @ 37degrees Celsius to start.
* Plasma exchange programme can always be altered during treatment and should be observed regularly during treatment to ensure correct settings.
* Programmes should be checked by two nurse’s pre-treatment.

# 11.1 Connecting and disconnecting Procedure

Plasma exchange treatment requires one to one nursing. If the patient is ventilated in ICU, the nurse: patient ratio of 2:1 is necessary i.e., one nurse for ventilation and one nurse for plasma exchange. Connection and Disconnection also requires two nurses. If treatment must be performed at ward level/ in the haemodialysis unit, a second nurse competent in Plasma Exchange Therapy is required for clinical support. Children who are agitated or confused are at increased risk on an exchange circuit as they may disconnect their circuit – the risks of treating children who are agitated, confused or aggressive with plasma exchange need to be weighed against the potential benefits. Early multi-disciplinary assessment is important to help mitigate these risks – consideration needs to be given to

 1). the proven benefit of the proposed treatment.

2).the risk of disconnection.

3). the staff ratio available for the duration of therapy.

4). options to modulate behaviour which may pose a risk.

5). whether alternative therapy might carry less risk overall.

*Connection:*

* Ensure program is correct.
* Confirm with consultant if patient is for single connection (bleed out) or double connection.
* Attach red line to access lumen of Central line and blue line to return lumen. Lines may be reversed if necessary.
* Commence blood pump as per prescription and increase blood flow as patient tolerates.
* Do not commence plasma exchange turnover until patient is safely established on circuit and tolerating blood pump speed; this requires not pressing the balance/ treatment key until the patient is safely established on the circuit.

*Management:*

* Obtain blood samples as directed by consultant.
* Ensure to also reserve blood for ‘immunoglobulin’s (IgG, IgA and IgM)’ and ‘coagulation screen’ prior to commencement of the session as clotting factors and immunoglobulin’s can be depleted with TPE. Discuss frequency of these blood tests with consultant (Winters 2012).
* Record Paediatric Early Warning Score (PEWS) once patient is connected and then every 30 minutes or more frequently if patient’s condition dictates. Nurse on continuous ECG and O2 saturation monitoring
* Be vigilant for cardiovascular instability due to fluid changes and ensure that the patient tolerates the extracorporeal volume- observe heart rate, blood pressure, capillary refill, and pulse volume.
* If hypovolemic, patient may require a fluid bolus- ensure rescue fluids are prescribed.
* Sessions last approximately 2-3 hours but the length of time depends on the volume of plasma to be exchanged and how well the child tolerates the procedure.
* Consider the protein binding percentage of the patient’s medication as they may be cleared during TPE. Consult with team as medication timings may need to be adjusted (Winters 2012).
* Obtain VBG pre session and every 30 minutes for duration of session as patient is at risk of hypocalcaemia.
* Ensure Alfacalcidol is administered one hour pre session to minimise risk of hypocalcaemia.

|  |  |
| --- | --- |
|  Patients Weight  |  Dose of Alfacalcidol |
| Child < 20kg | 0.25micrograms |
| Child 20-40kg | 0.5micrograms |
| Child > 40kg | 1 microgram |

* Record ionized calcium on the nursing record sheet. Administer calcium gluconate if ionized calcium ≤ 1.0mmol. See **Appendix 3** for administration of Calcium Gluconate.
* Observe VBGs / ABGs for hypokalaemia. Consider Oral potassium supplementation.
* Obtain ACT 10mins into session and they should then be obtained every 30 minutes for duration of session. Titrate heparin dose according to ACT readings.
* Ensure patient’s temperature is above 36 degrees - use Bair Hugger warmer if needed.
* Ensure balance key is pressed off when handling replacement fluids to avoid wrongful alteration in plasma volume achieved.
* Counted balance alarms must be solved within 5 alarms or the machine will end treatment- it will allow a wash back. Therefore please identify reason for balance alarm as soon as possible.
* Ensure that last volume of replacement fluid (minimum of 100mls) infused to the patient is saline to ensure all blood product (plasma/albumin) is delivered to the patient.

## **11.2 Transmembrane Pressure (TMP) in Filter**

* Transmembrane pressure (TMP) is closely monitored throughout treatment.
* TMP should not exceed 50mmHg to protect the integrity of the membrane fibres and to reduce the risk of clot formation.
* Please be aware the Aquarius machine will only alarm if TMP is >100mmhg (Nikkiso 2021)
* A fast rise in TMP can be indicative of imminent filter clotting and patient disconnection should be considered if unable to resolve the high TMP (Puppe and Kingdon 2014).
* A slow rise in TMP can be monitored closely and session may not need to be terminated. In this instance, the plasma rate can be reduced (i.e., prolong the duration of the exchange). Plasma rate refers to the hourly rate of plasma removal and replacement from the patient. Additionally, the blood flow rate can be decreased to protect the filter (Nikkiso 2021).
* PR drop (the inverse relationship between the pre filter and return filter pressure) can be monitored in conjunction with TMP and a sudden rise in both can indicate a clot in which case the session may require termination to prevent loss of circuit.

*Disconnection:*

* Disconnect patient as per standard ‘Wash Back’ Procedure. Select **End treatment**.
* Ensure red access line connected to bag of normal saline 0.9% for wash back.
* Observe wash back and record volume.
* Flush both lumens with 10mls NACL and instil heparin as prescribed using positive pressure technique.
* Ensure circuit is removed prior to turning off Aquarius Machine.

# 11.3 Emergency Management

**Emergency Event**

Do not wash back if lines are clotted, i.e., blood looks black*,* or in the need to evacuate the unit.

If time allows flush lines and instil the heparin as prescribed.

**Cardiac Arrest**

In the event of cardiac arrest while the patient is undergoing plasma exchange, dial 2222 to alert arrest team and commence resuscitation protocols. Circulating blood volume should be returned to the patient. Central line should then be flushed to ensure patency as the line may be needed for access during arrest.

**Anaphylaxis**

In the event of anaphylaxis

* Stop the machine.
* Do not wash back blood
* Inform the medical team immediately and provide necessary treatment.
* Adhere to “Management of Transfusion Reaction Algorithm.

# 11.4 Complications

**Alkalosis** can be caused by metabolism of citrate to bicarbonate and the failure to excrete it adequately.

**Hypovolaemia** can occur because of a fluid shift that can arise because of a difference in oncotic pressure between the child’s serum albumin, and that of the replacement albumin solution. This may result in intravascular depletion with signs of dehydration - hypotension, tachycardia, peripheral vasoconstriction, nausea, or yawning. It is corrected by a bolus of NaCl 0.9% solution (10mls per kg).

**Hypervolaemia** occurs if fluid is pulled into the intravascular space because of differences in oncotic pressure. If fluid is drawn into the vascular space, the child may show signs of fluid overload, becoming hypertensive and even developing signs of pulmonary oedema. This may be prevented by the dilution of the replacement albumin with normal saline or giving intravenous furosemide.

**Hypothermia** A drop in peripheral body temperature will also occur if the child is becoming hypovolaemic and vasoconstriction is occurring to divert blood to vital organs. Hypotension and tachycardia will distinguish hypovolaemia from chilling. Use warmed replacement fluids. Wrapping the patient up in blankets or using a Bair hugger to trap body heat can prevent this.

**Dilutional hypokalaemia** is avoided by supplemental potassium. Signs and symptoms to look out for are bradycardia, muscle cramps and nausea. Monitor potassium level every 30 mins and administer oral potassium if required or foods / drinks rich in potassium. Observe patient’s bicarbonate level and discuss with Consultant Nephrologist / Intensivist **before** giving potassium supplementation.

**Hypocalcaemia** - citrate induced hypocalcaemia caused by the use of Octaplas as replacement fluid. Octaplas has Sodium citrate as a preservative which binds to the patient’s ionised calcium. Signs and symptoms to observe for include numbness and tingling particularly around the mouth or pins and needles in the fingers. Treatment is administration of calcium gluconate as per guidelines.

**Alterations to Clotting Times** Alterations to homeostasis are associated with plasma exchange. The severity of these will depend upon the volume and frequency of exchange, anti-coagulation and type of replacement fluid used. The underlying disease may also lower the intrinsic clotting factors e.g., SLE. Most patients are on anti-coagulation for the circuit. Observe circuit carefully. Consider alteration of heparin infusion or administration of Octaplas to replenish clotting factors removed during exchange.

**Allergic Reaction** An allergic reaction may occur from the blood products that are used during treatment or less likely from the filter used. Reactions range from urticaria and rash, to swelling and breathing difficulties. Adhere to algorithm in “Prescription and Administration Record for Blood Products” regarding management of acute transfusion reaction.

**Heparin Reversal** Therapeutic Plasma Exchange requires a high level of anti-coagulation to preserve the extracorporeal circuit and avoid clotting. In the event of over administration of heparin and subsequent bleeding, please contact haematology immediately and refer to the protamine protocol for HD for further guidance

[**http://templenet.cuh.net/wp-content/uploads/2019/08/Protamine-protocol-for-HD.pdf**](http://templenet.cuh.net/wp-content/uploads/2019/08/Protamine-protocol-for-HD.pdf)

**Air Embolism**

This is a rare complication since air detectors will clamp venous blood lines if air is detected in the return circuit. It may occur whilst manipulating central venous catheters. In sitting patients, air tends to move upwards into the cerebral venous circulation causing seizures and coma. In recumbent patients, it causes chest pain, dyspnoea, chest tightness and coughing.

 Management:

 Call for help. Clamp the venous line and stop the blood pump. Place the patient in the left lateral position, with head and chest down. Administer 100% Oxygen, via non-re-breather mask (enhances nitrogen diffusion out of air bubbles) and cardiopulmonary support, as necessary.

# 5.0 Monitoring, audit and evaluation

This PPPG will be reviewed and updated at least every three years by the document author/owner, or earlier if required due to updated guidance, evidence or legislation. Compliance with key principles or procedures described within this PPPG should be audited on an annual basis.

# 6.0 Key stakeholders

The following key stakeholders were involved in developing and/or reviewing this document:

|  |  |  |
| --- | --- | --- |
| **Name** | **Title**  | **Department** |
| Yvonne O Reilly | Clinical Nurse Manager 2 Therapeutic Plasma Exchange Service | Renal Unit  |
| Claire Mc Cabe | Haemodialysis CNS  | Renal unit |
| Grainne Bently | Clinical Nurse Manager 2 | Intensive care unit |
| Jennifer Caverly | Renal Pharmacist  | Pharmacy |

# 7.0 Communication and training

All approved PPPGs will be available on the Qpulse system. Heads of Department and Line Managers must ensure that their staff are aware of all PPGs relevant to their role and have access to same. Where required, training should be provided on the contents of this PPPG. One full day of training will be provided initially and full one to one support until competency achieved. On-going support and education will be provided by Plasma Exchange CNM2.

# 8.0 References

Ahmed, S., Kaplan, N. *Therapeutic Plasma Exchange using Membrane Plasma Separation.* Clinical Journal American Society of Nephrology. 2020 Sep 7:15 (9): 1364-1370.

Alhasan, K.A. 2019. *Therapeutic plasma exchange for children with kidney disorders:* Definitions, prescription, indications, and complications. Saudi Journal of Kidney Diseases and Transplantation,30(2), pp291-298.

American Nephrology Nurses Association. 2021. *Pediatric ESRD Hemodialysis Fact Sheet*

British Association for Paediatric Nephrology. 2008. Haemodialysis clinical practice guidelines for children and adolescents.

Bobati, S.S. and Naik, K.R. 2017. Therapeutic plasma exchange – an emerging treatment modality in patients with neurologic and non-neurologic diseases. *Journal of Clinical and Diagnostic Research,* 11(8), pp35-37.

Cortina, G, McRae, R., Chiletti, R. and Butt, W. 2018. *Therapeutic plasma exchange in critically ill children requiring intensive care*. Pediatric Critical Care Medicine,19(2), pp97-104.

Carter. C.E. and Benador, N.M. 2014*. Therapeutic plasma exchange for the treatment of pediatric renal diseases in 2013.* Pediatric Nephrology, 29(1), pp.35-50.

Eyre, M., Hacohen, Y., Barton, C., Hemingway, C. and Lim, M. 2018. *Therapeutic plasma exchange in paediatric neurology: a critical review and proposed treatment algorithm*. Developmental Medicine and Child Neurology, 60(8), pp765-779.

Heeyeon, C. 2020*. Pediatric Hemodialysis*. Childhood Kidney Diseases, 24(2), pp69-74.

Joseph, C., Siddiqui, S., Shah, S., Solomon, C.H. and Srivaths, P.R. 2021. *Therapeutic Plasma Exchange: single-center experience in children with kidney disorders*. Pediatric Nephrology,36(3), pp621-629.

Kaplan, A.A. 2013. *Therapeutic Plasma Exchange: A technical and operational review.* Journal of Clinical Apheresis, 28(1), pp.3-10.

Ipe, T.S. and Marques, M.B. 2018. *Vascular access for therapeutic plasma exchange.* Transfusion, 58(1), pp.580-589.

Nickson, C. 2020. *Apheresis, Plasmapheresis and Plasma Exchange*

Nikkiso. 2021. *Aquarius with Therapeutic Plasma Exchange (TPE)*: Practical Guide. <https://nikkisomedical.com/wp-content/uploads/2020/07/Aquarius-with-Therapeutic-Plasma-Exchange_A-Practical-Guide.pdf>

Norfolk, D. 2013. *Handbook of Transfusion Medicine.* 5th Edition. United Kingdom.

Puppe, B. and Kingdon, E.J. 2014*. Membrane and centrifugal therapeutic plasma exchange: practical difficulties in anticoagulating the extracorporeal circuit*. Clinical Kidney Journal, 7(2), pp201-205.

Sinha, A., Tiwari, A.N., Chanchlani, R., Seetharamanjaneyulu, V., Hari, P. and Bagga, A. 2012. *Therapeutic plasmapheresis using membrane plasma separation*. Indian Journal of Pediatrics, 79(8), pp. 1084–108

Winters, J.L.2012. *Plasma Exchange: concepts, mechanisms, and an overview of the American Society for Apheresis guidelines.* Haematology – American Society of haematology education programme ,1,pp7-12

# 9.0 Appendices

## Appendix 1 **PLASMA EXCHANGE ALGORITHM**

Requirement for plasma exchange decided by primary consultant

Meeting called by primary consultant with TPE CNM2 PICU& renal consultants and PICU & renal CNM3s aappropriate

Crumlin Plasma exchange Team

Escalate to site manager/ DNM & primary consultant

Can pool be offered to PLEX trained staff on ward & PICU?

Is there ICU staff available to perform treatment at ward level?

Review ward acuity to release haemo trained staff –to allow CNS perform PLEX. Can nursing admin back fill ward

Is PICU staffed and/or bed available to provide plasma exchange?

Plasma exchange on St Michael’s C – may require hybrid staffing

 PICU

Haemo roster reviewed to ensure PLEX trained staff available.

Is the HD unit staffed/bed available to provide plasma exchange? 1:1 nursing care will be required

Is the patient safe to be on a ward or requiring sedation?

## Appendix 2 Central Venous Access |Device Data

|  |  |  |  |
| --- | --- | --- | --- |
| **Permcaths** | **Size** | **Length** | **Priming Volumes** |
| Child 15-50kg  | 10fr | 28cm | A 0.8ml V 0.9ml |
| Child > 50kgs | 12fr | 36cm | A 1.3ml V 1.4ml |
| Medcomp Splitcath | 10fr | 18cm | A 0.8ml V 0.9ml |
| Medcomp Splitcath | 10Fr | 24cm | A 1.1ml V 1.1ml |
| Medcomp Splitcath | 14fr | 36cm | A 2.0ml V 2.1ml |
| Medcomp Splitcath | 14fr | 40cm | A 2.2ml V 2.3ml |

|  |  |  |  |
| --- | --- | --- | --- |
| **Vascaths** | **Size** | **Length** | **Priming Volumes** |
| Child < 10kgs | 6.5fr | 10cms | A 0.75 V 0.78mls |
|  | 6.5fr | 15cms | A 0.81 V 0.84mls |
| Child < 20kgs | 8fr | 10cms | A 0.80 V 0.82mls |
|  | 8fr | 15cms | A 0.88 V 0.90mls |
| Child > 20kgs | 11fr | 15cms | A 1.04 V 1.10mls |
|  | 11fr | 20cms | A 1.20 V1.26mls |

## **Appendix 3**

Guidelines for the Administration of Calcium Gluconate Intravenously during Plasma Exchange Therapy

* Commenced when ionized calcium ≤1.0 and **titrated as prescribed to maintain ionised Ca++ › 1mmol**
* Calcium gluconate 10% is used = 8.9mgs or 0.225mmol calcium per ml
* **Dose of calcium gluconate 10% = 0.5ml/kg = 0.11mmol/kg**
* Max dose calcium gluconate 10% = 20ml = 4.5mmol calcium

Dose and administration via intermittent infusion:

* **Dilute each 10mL calcium gluconate 10% with 40mL diluent** (a 1 in 5 dilution).(Diluents = sodium chloride 0.9% or glucose 5%).The resulting concentration is 0.045mmol/mL.
* **Initial Infusion rate = 1ml/kg/hr of diluted calcium gluconate solution** **via a central line. Adjust/increase rate as needed as per ionized calcium. (max infusion volume = 100ml = 4.5mmol).**
* Infusion may be stopped (or repeated) if necessary, according to ionized calcium.
* Monitor ionized calcium throughout and adjust or stop infusion as required.
* May be given more concentrated or undiluted via a central line as a slow IV injection over 5-10 minutes in emergencies.
* Calcium gluconate may cause venous irritation and tissue damage in cases of extravasation.
* If a central venous access device is unavailable, administer via a large peripheral vein, monitoring insertion site closely using a recognised phlebitis scoring tool. Re-site cannula at first signs of inflammation. Peripheral administration rate should not exceed 0.045mmol/kg/hr (or 1ml/kg/hour of diluted product) or in neonates 0.022mmol/kg/hr (0.5ml/kg/hr diluted product).
* Adverse effects: Administer slowly to minimise peripheral vasodilation, cardiac depression, and vasomotor collapse, possibly fatal. Rapid IV administration may also cause hypotension, bradycardia, cardiac arrhythmia, nausea, vomiting, flushing, and sweating.
* Monitoring: ECG monitoring, heart rate, blood pressure and plasma-calcium levels.
* Extravasation: Calcium salts are irritants. Extravasation is likely to cause tissue damage.
* **NB: Do not infuse with any other medicines or infusions (especially IV iron) unless compatibility has been established.**
* References: Paediatric injectable guide, Medusa, BNFc (all accessed online June 2018). Written by Jennifer Caverly, Renal Pharmacist.

**NB: Do not give IV Iron together with IV Calcium Gluconate as they interact**

**Appendix 4 Trouble Shooting**

Below are some common troubleshooting scenarios. For further troubleshooting please refer to the Aquarius Manual

**Blood Leak Alarm**

Whilst a ‘blood leak alarm’ can commonly occur during a plasma exchange therapy, an actual true blood leak is a very rare occurrence. Nursing staff must be vigilant for ‘blood leak alarms’ and be able to assess and manage them appropriately. Please be aware that

the Aquarius Machine has sensitivity to 4 ml of blood in 1 litre of waste plasma (Nikiso 2021).

If there is a ‘blood leak alarm’ with visible blood in the filter membranes:

* Stop treatment, **do not** wash the patient back and disconnect the child from the circuit.
* Contact the medical team to review patient and direct further management.
* Reserve bloods and send a Full Blood Count to check haemoglobin level.
* Consider need for a fluid bolus due to loss of the extracorporeal volume.

If there is a ‘blood leak alarm’ with no visible blood in the filter/filtrate –

* *Senior, experienced plasma exchange nurse* to assess patient and circuit.
* If there is no visible blood or rupture of filter membranes and a true blood leak is deemed unlikely, the following troubleshooting measures can be utilised:
* Ensure blood chamber is positioned correctly in its housing and filled with fluid
* Ensure that the blood leak sensor mirror is clean, as if not, this can cause a false blood leak alarm - Remove mirror from housing and clean and reassess circuit
* Avoid handling blood leak sensor as this may trigger a false blood leak alarm. Handle tubing at top of sensor instead.
* Observe filtrate – blood leak alarm may also be activated if removed plasma is cloudy. Consider termination of treatment if filtrate significantly blood stained
* Check the ‘more menu’ to check the ‘blood value’ – if value consistently >100% despite troubleshooting then consider it may be a true blood leak alarm and end treatment.

**High TMP**: if TMP is high it can be indicative of a clot. Recirculation of the circuit pre-treatment can help the filter to open and aid TMP. If TMP is elevated at the start of treatment, adjust, and tighten all 4 sensors. If taking sensors off, the blood pump must be stopped. If you have a true blood leak due to high TMP it will read greater than 100% in the more menu. If you do encounter a high TMP consider adjusting the blood flow and reduce the turnover rate. Ending the session must also be considered.

**Negative TMP**- there may be a negative TMP and it is not a reason for concern. It is most likely to occur at the beginning of a session when the pores of the filter are not saturated. Recirculation is recommended to saturate the filter and prime the filter to optimal state. This may improve filter survival and can be done after the pressure and clamp test.

**Positive arterial pressure**: check sensor to ensure it is inflated. Take care when flicking it as it may rupture, ensure blood pump is stopped. If there is an air bubble visible, increase blood flow to eliminate it. To ensure it is not a machine error, kink the access line for a few seconds. There should be a visible increase in arterial pressure. If it is a machine error, this will not occur.

**Temperature of substitution fluid**- temperature is set at 37 degrees. There may be variation of the actual recorded temperature from the machine. There should only be a difference of about 3-4 degrees. If there is a significant difference, the machine may require servicing if the substitution fluid is too cold. The temperature can be read in “more menu”.

Note: temperature may read lower than the “set” temperature due to the position of the heater sensor from the heater plate.

**PR drop**: is the inverse relationship between pre filter and post filter pressure. If it is high, it can be indicative of a clot- Consider this value in conjunction with TMP

**CPU Heater**: When treatment has been stopped for a period, due to balance alarms or bag changes, the fluid in the heater coil gets too warm . This leads to a cpu2 heater alarm and it will not start treatment until the heater and the fluid in the heater coil cools down. As a quick fix you can pull the fluid through with a syringe via the degassing unit, removing the air and some of the potentially too hot fluid, then start treatment again.

**Air Alarm:** In the event of an air detector alarm, the blood level dropping in the return chamber or air evident in the return line – connect syringe to bubble trap and then press air detector clamp key to open the return line clamp and remove air from the return chamber with a syringe on the bubble trap. If level in chamber is correct and no air visible in tubing, press the clamp key to close the return line clamp. Resume treatment by pressing the blood pump key.