PAEDIATRIC CARDIOPULMONARY BYPASS - HEART CENTRE FOR CHILDREN - CHW PERFUSION SERVICE

PRACTICE GUIDELINE ©

DOCUMENT SUMMARY/KEY POINTS

- The purpose of this Paediatric Cardiopulmonary Bypass Practice Guideline is to assist in the maintenance of continuity and quality of care provided by perfusion services at the Heart Centre for Children.
- Due to the dynamic nature of cardiovascular perfusion the information contained herein is not intended to replace common sense. Departure from this practice guideline requires communication between perfusionist, surgeon, anaesthetist and other involved parties.
- All perfusionists should be familiar with the function and operation, and when necessary, the calibration of all appropriate equipment necessary for the safe practice of perfusion.
- The perfusionist must assure that properly maintained equipment is used in the conduct of CPB.
- During CPB the perfusionist will monitor and maintain appropriate haematological and physiological parameters.
- During CPB appropriate myocardial preservation techniques should be carried out.
- The perfusionist should be prepared to conduct MUF on all patients if deemed necessary.
- The perfusionist should be aware of current perfusion emergency management techniques.
- The perfusionist must adhere to current Incident and Device Reporting procedure.

This document reflects what is currently regarded as safe practice. However, as in any clinical situation, there may be factors which cannot be covered by a single set of guidelines. This document does not replace the need for the application of clinical judgement to each individual presentation.

Approved by:	SCHN Policy, Procedure and Guideline Committee	
Date Effective:	1st April 2023	**Review Period**: 3 years
Team Leader:	Perfusionist	**Area/Dept**: Heart Centre, CHW Perfusion Services

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CHANGE SUMMARY

- Document due for a mandatory review. Minor changes made. Recommend reading the entire document.

READ ACKNOWLEDGEMENT

- The following are to read this document:
  - Perfusion team
  - Cardiac Surgeons
  - Cardiac Anaesthetists
  - Haematologists

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1 Practice Guideline Purpose

The purpose of this Paediatric Cardiopulmonary Bypass Practice Guideline is to assist in the maintenance of continuity and quality of care provided by perfusion services at the Heart Centre for Children. Provided in the following pages is the basic information necessary for the safe and effective conduct of paediatric perfusion in keeping with the 'Regulations and Guidelines for Perfusionists' published by the Australian and New Zealand College of Perfusionists (ANZCP).

Due to the dynamic and at times unpredictable nature of cardiac surgery and cardiovascular perfusion the procedural information contained herein is not intended to replace common sense and good judgment. The appropriate course of action in any situation is dictated by a combination of policy, common sense, and experience. Communication between the perfusionist, the surgeon, and anaesthetist is essential whenever a serious departure from established guidelines is undertaken.

2 Perfusionist Requirement

2.1 Certification

Cardiopulmonary Bypass should be conducted by a Certified Clinical Perfusionist (or a trainee in the direct presence of a Certified Clinical Perfusionist). Certification by the ANZCP Board or its equivalent meets this requirement.

2.2 Availability

The perfusion department, where possible, cover in-house, Monday to Friday from 0700 to 1900. After hours an on-call service is available via the hospital switch board. Two perfusionists are on-call at all times.

A perfusionist should conduct cardiopulmonary bypass with perfusion assistance usually present and always available.

For emergency situations, a perfusionist should be available within 45 minutes of the hospital.

2.3 CPB Conduct

During CPB the Perfusionist must:

- Adhere to universal precautions relating to potential blood product exposure.
- The perfusionist should have an unobstructed view of the heart-lung machine at all times.
- The perfusionist must be attentive and communicate clearly with other team members at all times avoiding all distractions.
- Any instruction from surgeon to perfusionist should be repeated clearly by the perfusionist as a means of confirmation (and vice versa).

- The perfusionist should never leave the heart-lung machine unattended at any time.
- The field of work should be clear.
- The perfusionist should be present in theatre from the time the chest is opened until the time it is closed.
- All waste should be segregated and disposed of into the correct receptacles, i.e. paper/packaging into bins, sharps into sharps container.
- The perfusionist must adhere to the ANZCP Standards of Clinical Practice and the Regulations and Standards concerning Clinical Practice as laid down by the ANZCP.

3 Equipment Selection Criteria

All perfusionists should be familiar with the function and operation, and when necessary, the calibration of all appropriate equipment necessary for the safe practice of perfusion.

All equipment is selected on the capacity of any given device to perform safely and effectively according to the published manufacturer specifications with respect to the blood flow rate prescribed for a patient by the following chart.

Patient Weight (kg)	Cardiac Index (L/min/m^2)
0 - 10	3.0
10 - 30	2.8
> 30	2.6

3.1 Oxygenator Selection Guideline

Type	Terumo FX05	Terumo FX05	Terumo FX15(30)	Terumo FX25
	1/4" Venous line to 1.2L/min	3/8" Venous line to 1.5L/MIN	3/8" Venous line to 4.0L/min	1/2"' Venous line to 7.0L/min
Blood Flow (L/min)	0.1 – 1.5	0.1 – 1.5	0.5 – 5.0	0.5 – 7.0
Gas Flow (L/min)	0.05 – 5.0	0.05 – 5.0	0.5 – 15.0	0.5 – 20.0
Surface Area (m^2)	0.5	0.5	1.5	2.5

Priming Vol. (mL)	43	43	144	260
Art. Filter (μ)	32	32	32	32

3.2 Tubing Pack Selection Guideline

Type	3/16 x 1/4	1/4 x 3/8	3/8 x 3/8	3/8 x 1/2
Blood Flow (L/min)	0 – 1.2	1.2 – 3.0	3.0 – 4.0	4.0 – 7.0

3.3 Pump Boot Selection Guideline

Type	1/4" Boot	3/8" Boot	1/2" Boot
Blood Flow (L/min)	< 2000mL/min	< 4000mL/min	>4000mL/min

3.4 Haemofilter Selection Guide

Type	Maquet BC60	Maquet BC20
Surface Area (m^2)	0.7	0.22
Max. Rated Blood Flow (mL/min)	500	100
Use With Circuit:	3/8x3/8, 3/8x1/2	3/16x1/4, 1/4 x3/8

3.5 Cannula Selection Guideline

The chart below is a guideline to appropriate cannula selection. Clinical conditions and anatomical variants may result in deviations from this chart.

Cannula selection is subject of approval by attending surgeon.

Weight (kg)	Arterial (Fr)	Single Venous (Fr)	Dual Stage (Fr)	SVC (Fr)	IVC (Fr)
0-5	8 (<750mL)	16-18		10	12-14
5-9	10 (<1100mL)	20-22		12	14-16
10-15	12 (<1700mL)	22-24		16	18-20
16-25	14 (<2500mL)	24		16	20
25-36	16-18	26		16	20
37-50	18		29/29	20	24
51-70	20		29/29	24	28
71-100	22		32/40	24	28
>100	24		36/46	28	28

4 Equipment Maintenance

The perfusionist must assure that properly maintained equipment is used in the conduct of CPB.

- The perfusionist should check for the function of all pumps before initiation of bypass for each case.
- Roller pump occlusions should be verified and adjusted as necessary before initiation of bypass for each case.
- Bubble sensor(s) should be checked before initiation of bypass for each case.
- Low level sensor should be checked before initiation of bypass for each case.
- Over pressure alarm/ pump stop should be checked before initiation of bypass for each case.

Preventive maintenance on perfusion equipment should be performed on a regularly scheduled basis. The interval of such maintenance may be determined by any or all of the following:

- Manufacturer recommendations.
- Institutional requirements.

5 Assembly of the CPB Circuit

CPB circuit assembly should be undertaken using a clean non-touch technique.

- Check overall cleanliness of the pump.
- Check availability of appropriate disposable equipment, ensuring back up equipment is available.
- Check integrity of sterile wrapped plastic bag containing all disposable equipment.
- Check all connection ports are capped.
- Hands should be washed thoroughly prior to assembly of the cardiopulmonary bypass circuit.
- Place the oxygenator unit into the holder, ensuring that it is seated correctly and secured.
- Assemble the cardiopulmonary bypass circuit, ensuring clean non-touch technique is observed for all connections.
- Ensure that all connections are secure and that all connections made with SRT tubing are tied with cable ties for added security.
- Flush assembled circuit CO_2 for a minimum of 5 minutes, prior to priming the circuit, ensuring pump boot, AV loop, and MUF circuit are all exposed to CO_2 flush.
- Pressure testing of the water phase of oxygenator and cardioplegia heat exchangers must be carried out before use.
- Heater cooler water temperatures should be set at 37-39°C.
- All pumps should rotate in an anticlockwise direction.

6 Circuit Prime Constituents

Prior to initiating CPB the circuit must be primed, debubbled and balanced. The post prime electrolytes must match the patients' pre-bypass levels as closely as possible unless indicated otherwise. It is recommended that the Sodium levels are no more than 10mmol/L different. Potassium should be no more than 2mmol/L different. Osmolarity should not exceed 290mmol/L. Circulating Colloid Osmotic Pressure (COP) should be 18-30mmHg.

The standard CPB prime has the following constituents:

- Plasmalyte 148- balanced electrolyte solution containing potassium, sodium, magnesium, acetate, gluconate, and chloride. This is an acidic solution and is usually buffered with 22mmol/L of Sodium Bicarbonate prior to infusion into the circuit.
- Sodium Bicarbonate ($NaHCO_3$) - used to buffer acidic prime constituents. A prime $NaHCO_3$ level of approximately 22-24 mmol/L is aimed for.
- Heparin- used for circuit anticoagulation. Amounts vary due to circuit size. Dose target is usually 100 IU Heparin per kg with a minimum of 1000 iu.. This means 1000iu in the prime for patients less than 10kg then 100iu/kg above 10kg. ie 12kg patient receives 1200iu.
- 20% Albumin- used for maintenance of colloid osmotic pressure (COP) and also to 'coat' the circuit PVC in order to ameliorate blood contact activation. Dose ranges from 50mL to 200mL depending on circuit size, and whether a blood prime is required. Target COP is 18-30mmHg.
- Calcium Chloride- used to prevent hypocalcaemia upon initiation of CPB. Amounts vary due to circuit size and patients ionized calcium level. Generally a prime ionized calcium of 1.0 – 1.2 mmol/L is aimed for.
- Water for Injections (WFI) - use of $NaHCO_3$ to buffer circuit prime often results in elevated prime sodium levels. The addition of water for injections to the prime ameliorates this. Amount required varies depending on circuit size. Caution- always administer WFI prior to blood.
- 50% Glucose – Glucose should be added to the prime if the prime glucose is <3mmol/L. For a circuit volume of 500mL 0.5mL 50% Glucose should be sufficient.
- Packed Red Blood Cells (PRBC's) – Where possible blood used to prime a CPB circuit should be washed in a cell salvage machine. A resultant Haematocrit (Hct) of 30% on CPB is targeted. If an asanguineous prime would result in excessive haemodilution, then the volume of PRBC's necessary to achieve this target range should be added to the prime. The resultant Hct on CPB utilising an asanguineous prime may be calculated using the following formula where IVBV = intravascular blood volume index (the appropriate value may be found in the table below).
- Fresh Frozen Plasma (FFP) – in infants it may be desirable to add FFP to a circuit prime. This is done to assist in the minimisation of dilution to a patients clotting factors, whilst permitting maintenance of an appropriate colloid osmostic pressure (COP). If the decision is made to add FFP to a circuit prime then ½ a bag (150ml) should be added to the prime pre-blood. In such cases only 50ml 20% Albumin would be required. Heparin

MUST be added pre FFP. The remaining FFP can be added whilst on bypass prior to its expiry time.

Patient Kilogram Weight Range	Intravascular Blood Volume Index
≤ 10kg	85 mL/kg
> 10 kg ≤ 20 kg	80 mL/kg
> 20 kg ≤ 30 kg	75 mL/kg
> 30 kg ≤ 40 kg	70 mL/kg
> 40 kg	65 mL/kg

- The volume of PRBC's necessary for a given target Hct on CPB may be calculated using the following formula:

  ? mL PRBC's = (((Target Hct / 100) x ((IVBV x kg) + mL prime)) - (IVBV x kg x (pt Hct / 100))) / 0.6

- Antifibrinolytics – These are rarely added to the circuit prime. If this is deemed necessary then the following regime should be followed.
  - Tranexamic acid (1000mg/mL) – Loading dose 30mg/kg/dose. Pump prime 30mg/kg OR infusion 10mg/kg/hr. If using boluses final dose of 30mg/kg can be used after separation from bypass.
  - Aprotinin (1mL=10000KIU) – Loading dose: 50000units/kg (5mL/kg for kids up to 10kg). Pump prime: 10000units/100mL prime volume (1mL/100mL). Infusion (if pump prime not loaded): 10000units/kg/hr (1mL/kg/hr). Each mL contains 10000 kallikrien inhibitor units (KIU) 1.4mg/mL, Max: 500000units (1 bottle).

All CPB related drugs are to be drawn up with attention to sterility with syringes labelled appropriately at the time.

7 Circuit Priming Procedure

- Prior to running fluid into the circuit ensure the pump is turned on with all pressure parameters active. Ensure that all pressure parameters are 'zeroed'.
- Prior to running fluid into the circuit connect and enable the level sensor ensuring that it is operational.
- Circulate the crystalloid prime through the cardiopulmonary bypass circuit, ensuring the removal of all visible air (if clamps are required ensure they are never used on polycarbonate devices or connectors).
- Run the arterial pump and pressurise the system by partial occlusion of the venous line to achieve a pressure of 100-200 mmHg (never exceed the maximum rated flow rate for any circuit components).
- Visually inspect the complete cardiopulmonary bypass circuit for leaks and/or visible air.

- Always invert cardioplegia heat exchanger during priming inspect for visible air.
- Once satisfied that circuit is air free, flow can be ceased, and the pre-bypass filter removed). ALWAYS remove the pre-bypass filter prior to blood priming.
- Ensure the arterial, venous and cardioplegia temperature probes are in place.
- Connect and enable arterial and cardioplegia bubble detectors.
- Set alarms appropriately.
- Complete Pre-Bypass Checklist (see section 11).

8 Safety Device Usage

The perfusionist must use appropriate safety devices during CPB.

The following devices should be employed:

- Low level detector.
- Arterial line bubble detector.
- Cardioplegia line bubble detector.
- Ventilating Gas Oxygen Analyser (situated after any other line inclusions).
- Anesthetic gas scavenge line.
- Pressure relief, and where appropriate one way valves, in all suckers and vent lines.

9 Monitoring Device Usage

During CPB the perfusionist must employ appropriate monitoring devices.

The following devices should be employed:

- Blood flow indicator.
- Gas flow meter.
- CPB circuit pressure monitor.
- Patient Physiologic monitor.
- Patient and Circuit Temperature monitors.
- Timers.
- Blood gas analyser.
- ACT monitor.
- NIRS monitor (as required).

10 Alarm Setting

10.1 Low Level Alarm

During CPB the perfusionist must maintain a safe operational volume in the venous reservoir in order to permit sufficient reaction time in the event of a decrease in venous return. As a safeguard a low level detector should always be used.

The low level alarm sensor should be applied no lower than the manufacturers recommended low level operating volume.

The low level alarm must be activated at all times during CPB and Modified Ultra Filtration (MUF). The low level alarm will stop both arterial blood pump and cardioplegia blood pump.

10.2 Arterial Pressure Alarm

The arterial line pressure alarm should be 'zeroed' to atmosphere before each case. The arterial pressure alarm should be set to STOP no higher than 320mmHg, and set to ALERT at approximately 300mmHg. These values should always be viewed in conjunction with an awareness of the patient's anatomy, cannula size, and flow requirement. Any concern over arterial pressure should be communicated immediately to the surgeon. The arterial pressure alarm will stop the arterial blood pump.

10.3 Cardioplegia/ MUF Pressure Alarm

The cardioplegia/ MUF pressure alarm should be 'zeroed' to atmosphere before each case. During cardioplegia delivery the pressure alarm should be set at 220-240mmHg. This will stop the pump should a major restriction be present on the line. The perfusionist must monitor the displayed value, during cardioplegia delivery, with an awareness of the delivery technique being employed. This knowledge will enable the perfusionist to judge whether the delivery pressure displayed is appropriate. Any displayed pressure that is deemed inappropriate must be communicated to the surgeon immediately. The cardioplegia/ MUF pressure alarm will stop the cardioplegia/ MUF blood pump only.

The table below is a guide to expected pressures (antegrade pressures are maintenance pressures and not the pressure required to close the aortic valve):

Antegrade Delivery	Retrograde Delivery	Ostial Delivery
45-100mmHg	<150mmHg	<200mmHg

10.4 Negative Arterial Pressure Alarm

The second arterial line pressure alarm should be activated when the pump is pressurised. This channel will alarm if any negative pressure is detected on the arterial side of the circuit. The alarm limits are set to alarm at 0mmHg and stop the arterial blood pump at -2mmHg.This is essential during MUF when blood is being drawn retrograde through the circuit. It may be necessary to turn off this alarm during certain circumstances, such as circulatory arrest. Care must be taken to reinitiate this alarm.

11 Pre-Bypass Checklist

The perfusionist must complete and electronically sign a pre-bypass checklist prior to initiation of cardiopulmonary bypass. This checklist is part of the Connect bypass record.

12 Perfusion Record

An essential component of CPB is an accurate perfusion record.

The perfusion record should include the following patient information:

Patient Data

- Patient Medical Record Number.
- ECC Number
- Date of Surgery
- Name
- Date of Birth / Age.
- Gender.
- Transferred from

- Physique
  - Height
  - Weight
  - BSA
  - Calculated flow
  - Blood group
  - Urgency
- Clinical Data
  - Diagnosis
  - Procedures
  - Allergies
  - Infections
- Surgical team
  - Perfusionists
  - Surgeons
  - Anaesthetists
  - Physiologists
- Products
  - List of disposable components with Lot numbers
  - List HLM and HCU number
  - List all used cannula sizes and position
- Priming
  - List all prime components and volumes/ doses
  - List any prime filtration to ensure accurate fluid balance
- Blood gases
  - Document patient pre operative ABG
  - Document prime gas
  - During bypass ABG should be carried out and recorded every 30 minutes or as required. The CDI 500 should be calibrated against these gases.

- Coagulation
    - Document patient pre operative ACT
    - During bypass an ACT should be carried out and recorded every 30 minutes or as required.
- Implants
    - Document the size, position, location and manufacturer/ provider of any valves, stents, or grafts used.

In addition to the above data, during bypass any comments, drugs or fluid in/out must all be recorded diligently. The Connect system has many commonly used pre filled parameters that can be used to save time. This record should also reflect any pertinent communication points between members of the team which may include instructions or comments.

All physiological patient data and pump data (including the CDI550) should be recorded automatically every 20 seconds by the Connect data management system, or at a manual frequency of at least every 10 minutes in the advent of a Connect failure. A manual record must include the following:

- Blood flow rates.
- Arterial line pressure.
- Arterial blood pressure.
- Central venous pressure.
- Input fluid volumes
- Output fluid volumes
- Arterial blood gases.
- Venous oxygen saturation.
- Patient nasopharyngeal temperature.
- Activated Clotting Times (ACT).
- Medications and/or inhalational anaesthetic agents administered via extracorporeal circuit.
- Additional haematological or physiological data:
    - Patient arterial/ venous blood gases (ABG/ VBG).
    - Plasma Free Haemoglobin (pfHb).
    - Near Infrared Spectroscopy (NIRS).
- Comments:
    - Information given to Surgeon pertaining to unusual or potentially problematic events.
    - Communication from surgeon requesting deviation from standard practice.

The perfusion record should be checked, printed out and placed in the patient's medical record. A detailed copy of the perfusion record will be retained in the perfusion database.

As much detail as possible should be put into the perfusion record as it is a legal document and protection for the perfusionist.

13 Anticoagulation

The perfusionist shall monitor the coagulation status of the patient pre, during and immediately following the procedure. Unless otherwise indicated heparin is the anticoagulant of choice.

13.1 Pre-operative coagulation monitoring

Prior to the procedure the perfusionist should view the patients' blood tests relating to coagulation to detect any possible issues. These tests should include but are not limited to:

- Platelet count (150 to 600 ($x10^9$/L)).
- Prothrombin Time (PT) (11 to 15 sec).
- Activated Partial Thromboplastin Time (APTT) (23 to 34 sec).
- International Normalised Ratio (INR) (1 to 1.2).
- Fibrinogen (1.5 to 6 g/L).
- ACT (90 to 150 sec).

13.2 Intraoperative anticoagulation monitoring

Upon the surgeons request the anesthetist shall administer a full systemic heparin dose to the patient. This shall be 400u/kg for patients less than 10kg, or 300u/kg for patients greater than 10kg. If this request is not made it is the perfusionist's responsibility to voice this to the team and NOT commence CPB without heparin being given.

Following heparinisation of the patient an ACT must be checked. This blood is taken from the patient, through an access line of the anaethetists preference usually 90 seconds following heparin administration. CPB is not generally initiated until the measured ACT has exceeded 400 seconds as measured by the Hemochron Signature Elite (or 3 times the baseline value). An ACT of 300 seconds is also representative of a 'safe' time to turn on the pump suckers.

If the ACT does not reach 400 seconds this must be communicated to the surgeon and anaesthetist immediately and additional heparin dose is discussed with the anaethetist. If additional heparin is given, the decision to commence bypass without an additional ACT

If an acceptable ACT is unable to be achieved consideration should be given to the administration of anti-thrombin III concentrate or fresh frozen plasma. This would then be followed by the rechecking of the ACT.

If the surgeon demands the suckers be turned on prior to an acceptable ACT being reached the awareness of the ACT should be confirmed with the surgeon. If the order still stands then the perfusionist may consider inserting additional heparin directly into the sucker line or cardiotomy reservoir, turning the suckers on and documenting the course of action. If the perfusionist is still concerned the sucker blood could be directed to a blood bag and thus potential contamination of the cardiotomy reservoir prevented.

If the surgeon requests initiation of CPB prior to an acceptable ACT being reached the awareness of the ACT should be confirmed with the surgeon. If the order still stands then the perfusionist should voice their concern and once again and ask if this course of action is in

the patient's best interest. If the order still stands CPB should be commenced and the course of action documented.

During CPB an ACT from the CPB circuit should be taken within 10 minutes of commencement of CPB and at least every 45 minutes during CPB. When interpreting the result the perfusionist should always take into account the patient temperature and administer additional heparin to maintain an ACT of at least 480 seconds.

More frequent ACT measurement may be warranted following administration of additional heparin, following administration of fresh frozen plasma (FFP) into the circuit, following rewarming, or following hemofiltration.

13.3 Post-operative coagulation monitoring

Following cessation of CPB, and upon the surgeon's request, protamine will be administered to the patient by the anesthetist. Once half of the protamine dose is administered the CPB pump suckers must be turned off. In the event of ongoing bleeding the pump suckers may be turned off earlier in order to prevent contamination of the circuit by shed blood containing protamine.

An ACT will be checked following protamine administration in order to confirm heparin reversal.

The perfusionist may carry out TEG's during the immediate postoperative period to assist in decision making around blood product use.

13.4 Heparin Induced Thrombotic Thrombocytopaenia Syndrome (HITTS)

In cases where a patient is suspected, or proven, to have HITTS a heparin alternative should be used. See HITTS management guideline (currently under development).

14 Initiation of CPB

- Once an acceptable ACT has been achieved, and either immediately prior to or just after aortic cannulation, the surgeon will request to "divide the lines".
- The pump is stopped, the arterial and venous line are clamped (ensure the AV loop is not overly pressurised).
- Any purge or recirculation lines should be closed.
- The circuit should be pressurised to a level just greater than the patients MAP.
- The negative arterial pressure alarm should be activated.
- The surgeon should then be informed that you are "happy for them to divide the lines".
- The surgeon will clamp and divide the arterial and venous lines.
- If the circuit is blood primed the request will be made to "release the venous line", at this stage the perfusionist should release their venous clamp and thus drain any excess volume from the AV loop into the venous reservoir. The venous clamp must then be reapplied. Care must be taken not to allow the fluid in the venous line to drain too far

down the venous line as this will increase the chance of an air lock upon commencement of CPB.

- After cannulation of the aorta, the surgeon will remove the clamp on the arterial line and inform the perfusionist that “the arterial line is open”.
- The perfusionist will then assess the arterial line by removing the arterial line clamp, watching the arterial line circuit pressure (this should be within 10-15mmHg of the patients MAP), a short period of forward flow should be observed to check for correct cannula position. Incorrect positioning will result in a rapid increase in arterial line pressure
- The perfusionist must then communicate to the surgeon the acceptability, or otherwise, of the arterial cannula.
- Once the aorta is cannulated, the venous cannula is/are inserted.
- If bicaval cannulae are to be inserted bypass will usually begin with the placement of one of these.
- Bypass will be initiated when the perfusionist is satisfied that it can be safely done so, and on the instruction of the surgeon.
- Oxygen/ Isoflurane will be added to the circuit sweep flow, and the arterial pump will be started slowly.
- The venous clamp will then be removed in conjunction with the arterial pump speed being increased.
- During the early stages of bypass initiation normovolaemia should be maintained. In the event of bypass needing to be immediately terminated, this would leave the patient in a position to support their own circulation.
- Feedback should be given to the surgeon on the achievable flow without filling the patient. Full flow may not be obtainable until the second venous cannula has been inserted.
- If a clear prime has been used it is preferable to go onto bypass with a partial clamp on the venous line. This is to assist in keeping the heart ejecting in order to permit mixing of native venous return to the heart and the circuit prime. When adequate mixing has been achieved the partial clamp can be removed.
- Once full estimated flow is reached announce “full flow” clearly so that the surgeon is aware and also so the anaesthetist can be permitted to stop ventilation. Ideally full flow is the achievement of the patients estimated flow requirement with suitable off-loading of the heart manifested by a CVP <5mmHg and a non-pulsatile arterial wave form.
- During the initiation of bypass the arterial line pressure should be frequently checked in order to ensure that excessive pressure is not being generated.
- Displayed values on the CDI500 should be checked and FiO2 and sweep adjusted accordingly.

14.1 Retrograde Autologous Priming (RAP)

As part of a patient blood management strategy it may be required to carry out RAP prior to, or upon commencement of CPB.

- RAP arterial line
  - Ensure the negative arterial pressure alarm is activated, and the anaesthetist is aware of the intention to RAP and prepared to administer pressors if required.
  - Using a dual limb retransfusion bag, attach one end to a 3 way tap placed on the reservoir with the oxygenator recirculation line on the other port of the 3 way tap.
  - Following aortic cannulation, ensure forward flow is possible.
  - Open the 3 way tap so gravity permits flow to run, in a retrograde manner, from arterial cannula to retransfusion bag.
  - Observe arterial line pressure, patient MAP, and patient CVP. If MAP drops pressors should be given.
  - Observe for activation of arterial bubble sensor.
  - If MAP and CVP drop rapidly, prepare to clamp, or partially clamp RAP line to limit or slow the process.
  - Once red cells are seen in the limb of the RAP bag clamp the line and inform the surgeon RAP is complete.
  - Leave the RAP bag connected to the reservoir so the fluid can be added to the venous reservoir if additional fluid is required.
- RAP venous line (NB not technically retrograde)
  - Using a dual limb retransfusion bag, attach one end to the safesite valve on the MUF/plegia line.
  - Place a clamp distal to the cardioplegia bubble sensor, and proximal to the safesite valve- this is to prevent any air progressing up this line.
  - Upon commencement of CPB leave the venous line clamp insitu (this must be placed distal to the entry point of the MUF circuit, and proximal to the venous inlet to the reservoir.
  - Open the clamp on the limb of the RAP bag and permit the blood from the venous system to displace the crystalloid in the venous line into the RAP bag.
  - Once red cells are seen entering the RAP bag this should be clamped, and the venous line clamp simultaneously removed.
  - Bypass should then be initiated as usual with a clear prime (i.e. with a partial clamp on the venous line until adequate blood/ crystalloid mixing occurs).

Once the RAP process is complete the clamp on the plegia/ MUF line can be moved from proximal to the RAP bag to distal to the RAP bag. When the MUF blood pump is activated blood can now displace the crystalloid in this part of the circuit into the RAP bag. Once red cells are seen entering the RAP bag it should be clamped, and simultaneously remove the

clamp from the plegia/ MUF circuit permitting the blood to recirculate back to the venous reservoir.

The RAP bag can now be removed from the safesite valve and capped.

15 Blood Gas Maintenance

During CPB appropriate gas exchange shall be maintained. Appropriate oxygenator gas flow rate and concentration should be determined by using blood gas analysis which includes use of the CDI 500 monitoring device in conjunction with point of care (POC) blood gas analysis at least every 45 minutes.

Further determinations may be guided by the colour of the blood, oxygenator directions for use, and perfusion parameters such as blood flow rate and temperature.

It is particularly important to keep the PaO_2 in the low end of the range during the initiation of CPB (especially for cyanotic patients), during myocardial reperfusion, and during re-initiation of CPB following deep hypothermic circulatory arrest (DHCA) or antegrade selective cerebral perfusion.

All blood gas calculations are performed as alpha stat unless the patient is to be cooled below 28°C, during which pH stat cross-over technique is used. This involves the patient being cooled utilising pH stat blood gas management. As the patient approaches the hypothermic temperature hyperoxygenation will commence. After Circulatory arrest period has ended and flow is reintroduced change back to alpha stat for rewarming.

16 Blood Flow Maintenance

During CPB the perfusionist shall maintain an appropriate blood flow rate. Calculated blood flow rate should be determined prior to cardiopulmonary bypass using the patient's body surface area (BSA) (see section 3).

The cardiac index is not an absolute value, and blood flow on bypass is adjusted according to physiological requirement.

Appropriate blood flow rate should be determined by evaluation of a combination of:

- Venous oxygen saturation
- Body surface area
- Arterial blood pressure
- Temperature
- Lactate
- NIRS
- Oxygen consumption
- Collateral circulation

In the event of poor venous drainage it may be necessary to augment venous return with the aid of Vacuum Assisted Venous Return (VAVD). For the safe use of this technique refer to the VAVD policy: http://webapps.schn.health.nsw.gov.au/epolicy/policy/4398

17 Patient Blood Pressure Maintenance

During CPB the perfusionist shall maintain an appropriate patient blood pressure.

It is essential that during the procedure the patient's arterial blood pressure is monitored and recorded. The perfusionist should be aware of the location of the patient's arterial line as anatomical variances and surgical cannulation strategies may have a direct influence on this value. At times it may be necessary to monitor and record upper and lower body arterial blood pressures.

The maintenance of arterial blood pressure may be influenced by factors other than the conduct of cardiopulmonary bypass.

The perfusionist may alter flows and/ or manipulate the concentration of anesthetic gas (Isoflurane) in order to assist in the maintenance of an acceptable blood pressure. Any alteration in flow must be done with an awareness of the effect on arterial line pressure and systemic perfusion.

It is often necessary to administer vasopressors in order to maintain an acceptable patient blood perfusion pressure. Administration of such pharmacological agents should be done in conjunction with the anaesthetist.

17.1 Desired Mean Arterial Blood Pressure

Systemic arterial blood pressure is maintained in the range 40-50mmHg for neonates and infants and 50-65mmHg for older patients.

17.2 Low MAP Intervention

- Verify closure of all recirculation lines.
- Compensate for blood steal whenever an arterial purge line is open, during cardioplegia delivery, hemofiltration, and aortic vent usage.
- Lower isoflurane delivery if depth of anesthesia is adequate.
- Ascertain presence of A-V shunts. Consult surgeon.
- Increase blood flow rate until either adequate MAP or the upper limit of blood flow rate range is reached, or as surgical conditions permit.
- Ensure the absence of vasodilator infusion.
- Administer vasopressor boluses until an adequate MAP is obtained.

17.3 High MAP Intervention

- Inhalational Isofluorane is administered via a vaporiser in the gas line between blender and oxygenator. Standard dosage is 0.6 - 1.0% continuously, with 0.5% increases if the blood pressure rises above a mean of 50mmHg for neonates and infants and 65mmHg for older patients. Administration of isofluorane at > 2.0% for prolonged periods should ideally be avoided.

- Consult the anaesthetist as to whether opioid or muscle relaxer agents should be administered.
- Lower blood flow rate if SvO_2 > 70%.
- In consultation with anaesthetist consider vasodilator use.

18 Central Venous Pressure (CVP) Maintenance

During CPB the CVP should ideally be < 5 mmHg. An elevated CVP can result in hypoperfusion, hypervolemia, and edema, particularly when the MAP is low.

In the event of an elevated CVP:

- Verify that the venous line is not occluded.
- Ask the anaesthetist to check the patient for evidence of facial edema, the patency of the CVP monitoring line, and the zero and calibration of CVP transducer.
- Ask the anaesthetist to consider moving the CVP measurement from the distal lumen to the proximal lumen.
- Ask the surgeon to check the position of the venous cannula.

19 SvO_2 Management

In general a SvO_2 value of > 70% is aimed for. An acceptable SvO_2, in isolation, is not a guarantee of adequacy of perfusion. A low SvO_2 is usually a reliable indicator that perfusion is not adequate.

In situations of a low SvO_2 consider:

- Increase blood flow rate.
- Reduce oxygen consumption by:
  - Increase isoflurane delivery.
  - Request anaesthesia considers optimising intravenous anaesthetic.
  - Deepen hypothermia.
- Increase FiO_2.
- Add PRBC's.

Low SvO_2 Management at low blood flow rate

- If maintaining 1/2 or 1/4 blood flow rate at the surgeon's behest, consider deepening hypothermia and/or adding PRBC's.
- Consult the surgeon.

20 Near Infrared Spectroscopy (NIRS) Management

NIRS monitoring will be used on all cases requiring CPB.

NIRS monitoring is placed on the forehead and the lower back. On larger patients or patients undergoing ACP, bilateral forehead probes will be applied. Patients above 30kg do not have lower back (somatic) NIRS unless specifically requested. Placement of NIRS sensor is at the discretion of the anaethetist.

There is currently no interventional algorithm in place for NIRS data. Variations greater than 20% in NIRS data which do not respond to perfusion intervention are to be communicated to the team by the perfusionist.

21 Electrolyte Management

21.1 Calcium (Ca++)

Generally an ionized Ca++ level of approximately 0.8- 1.0 mmol/L is maintained during CPB until 15 - 20mins after myocardial reperfusion. Approximately 15 - 20mins after myocardial reperfusion, and prior to separation from CPB, correct the ionized Ca++ level to approximately 1.2 mmol/L.

21.2 Potassium (K+)

During CPB a normal K+ range of 3.5 - 5.5 mmol/L is aimed for. If, for example after multiple doses of cardioplegia, a patient becomes hyperkalemic this can be corrected by conducting hemofiltration replacement therapy with buffered 0.9% saline.

22 Glucose Management

A normal paediatric Glucose range is considered to be 4.0- 6.0mmol/L.

22.1 Causes of Progressive Hyperglycemia during CPB

- Surgical stress.
- Hypothermia.
- Cardioplegia solution.
- IV solutions containing glucose.
- Preoperative steroid administration.

22.2 Clinical Treatment of Hyperglycemia during CPB

Glucose levels during CPB should be kept <15mmol/L. To manage hyperglycemia consider:

- Haemofiltration replacement therapy with buffered 0.9% saline or Plasmalyte 148.
- Upon consultation with the anaesthetist insulin administration could be considered.

23 Renal Function Monitoring

During the period of CPB the urine output should be monitored. An acceptable level would be >1.0mL/kg/hr for children <1 year old and >0.5mL/kg/hr for children >1 year old.

Where the output is less the anaesthetist should be informed and the use of diuretics considered.

24 Cardioplegia Guideline

Cardioplegia may be delivered at varying locations, temperatures, pressures, concentrations, and for varying time periods.

For information pertaining to expected cardioplegia delivery pressures see Section 10.3.

Two different cardioplegia solution options are available. Each solution entails different considerations and different settings on the HLM. Great care must be taken to ensure the settings on the HLM are appropriate for the chosen solution and strategy.

24.1 AHK5560 Cardioplegia

24.1.1 Heart-Lung Machine consumable setup

Ensure that the cardioplegia crystalloid administration line enters the cardioplegia circuit post heat exchanger.

24.1.2 S5 Cardioplegia Control Module Settings

Please ensure the cardioplegia module settings reflect the below tables:

Menu 1/4	
Type of Cardioplegia	Manual
Type of Dose	First Dose
Volumetry	====>

Through the Volumetry tab

Volumetry Select	Amount
Initial Dose	2.000
Dose Volume	2.000

Menu 3/4	
Controlled Pump (*Upper*)	CPG Blood(2A)
Controlled Pump (*Lower*)	CPG Crystalloid (2B)
Flow Ratio	3:1

24.1.3 Dose

The induction dose of cardioplegia is administered over 4 minutes at a flow rate of 110mL/m2/min. Subsequent doses are over 2 minutes at a flow rate of 110mL/m2/min.

24.1.4 Re-Dosing times and amounts

The surgeon should be notified at 20 minutes post cardioplegia dose and re-dosing commenced upon their instruction.

24.1.5 Delivery technique

Concentration of blood: crystalloid should initially be set at 3: 1, with the crystalloid concentration being reduced once the heart is arrested, in order to prevent hyperkalemia and avoid administering large amounts of crystalloid to the myocardium.

The cardioplegia administration temperature should be initially 32°C and reduced to 25°C once the heart is arrested. An exception to this rule would be if the patient has already been cooled to a temperature lower than the 32 or 25°C. In such a case the cardioplegia temperature should be set at the patient temperature or just lower than this.

Maintenance doses of cardioplegia should be administered at the same flow rate, over 2 minutes, at 25° C, at a concentration of 4:1 at its most concentrated.

24.2 del Nido Cardioplegia

del Nido cardioplegia is an extracellular solution that is intended to provide myocardial protection for extended periods with little or no subsequent doses beyond the induction dose. It differs from other blood mix cardioplegia strategies in that the ratio of crystalloid to blood is reversed, with there being four parts crystalloid to one part blood. A key tenet of del Nido in comparison to other forms of cardioplegia is the amount of calcium in the resultant mixture. As the base solution contains no calcium, the only source is from the patient's blood, resulting in what is described as a trace amount, which is considered to be preferential to both normal or acalcaemic cardioplegia.

24.2.1 del Nido Constituents

The del Nido cardioplegia is prepared by the addition of components to a base solution of Plasmalyte 148. Plasmalyte 148 is a crystalloid solution containing; sodium 140 mmol/L, potassium 5 mmol/L, magnesium 1.5 mmol/L, chloride 98 mmol/L, acetate 27 mmol/L and gluconate 23 mmol/L.

Added to 1 litre of Plasmalyte 148:

Agent	Amount	Purpose
Potassium Chloride 3 mmol/mL	8.7 mL	Myocardial cell depolarisation
Lidocaine 10%	1.3 mL	Sodium channel blocker, hyperpolarising agent
Mannitol 20%	16.3 mL	Osmotic pressure, free radical scavenger
MgSO4 2 mmol/mL	4 mL	Calcium channel blocker
NaHCO3 8.4%	13 mL	pH buffering

24.2.2 Heart-Lung Machine consumable setup

Ensure that the cardioplegia crystalloid administration line enters the cardioplegia circuit pre-heat exchanger, rather than post, which is required to cool the greater thermal mass of combined cardioplegia delivered.

24.2.3 S5 Cardioplegia Control Module Settings

Please ensure the cardioplegia module settings reflect the below tables:

Menu 1/4	
Type of Cardioplegia	Automatic
Type of Dose	First Dose
Volumetry	====>

Through the Volumetry tab

Volumetry Select	Amount
Initial Dose	Calculated dose (20 mL/kg)
Dose Volume	Calculated dose (20 mL/kg)

Menu 3/4	
Controlled Pump (*Upper*)	CPG Crystalloid (2B)
Controlled Pump (*Lower*)	CPG Blood (2A)
Flow Ratio	Manual

24.2.4 del Nido Dose

Generally given as single dose 20ml/kg/dose. A smaller arresting dose of 10 mL/kg may be used for procedures requiring a crossclamp time less than 30 minutes.

Additional cardioplegia volume may be given for hypertrophied hearts, those with aortic insufficiency, or those with known coronary disease based on the effectiveness of the initial dose and surgeon preference.

The maximum arresting dose is usually limited to 1 L for patients larger than 50 kg.

Subsequent doses are not normally given except for the rare occurrence of electrical activity or for long cross-clamp times (see below).

24.2.5 Re-Dosing times and amounts

Notify Ischaemic Time	Anticipated Ischaemic Time Remaining	Dose
60 Minutes		No action
90 Minutes	Less than 30 Minutes	Nil additional cardioplegia
90 Minutes	30 to 60 Minutes	Half dose (10 mL/kg)
90 Minutes	Greater than 60 Minutes	Full dose (20 mL/kg)
120 Minutes		Surgical discretion
Breakthrough ECG		Surgical discretion

24.2.6 Delivery Technique

When the arterial pump is stopped for the A-V loop to be divided, the water tank for the cardioplegia heat exchanger is switched to the cold tank with a preselected temperature of 2^{o}C.

Upon initiation of bypass, the cardioplegia pump (in Manual mode) is to be recirculated for at least 2 minutes, to ensure thorough mixing of the prime perfusate with the patient's blood.

After the minimum 2 minutes, the cardioplegia blood pump is stopped and the cardioplegia ratio is then set to 4:1. Following this, control of the cardioplegia delivery is achieved by adjusting the Cardioplegia Crystalloid pump (2B) dial. Recirculation is then recommenced with a flow rate of 100 mL/min on the crystalloid pump and recirculated for at least 45 seconds to displace the blood perfusate with cardioplegia solution throughout the heat exchanger and delivery line.

During this recirculation period, it is advisable to check that with the crystalloid pump running at 100 mL/min, the blood pump is running at 20 mL/min, thereby double checking that the correct ratio has been selected.

When the cross-clamp is applied to the aorta, the cardioplegia delivery mode icon is selected, and the delivery is commenced at a flow rate of 7 - 10 ml/kg/min, maintaining a delivery line pressure of 50 – 100 mmHg. The volume to be delivered is displayed going down on the cardioplegia module and when the entire dose is complete, the pumps will stop automatically and sound a tone. Note: if a 20ml/kg dose is administered at 10ml/kg/min this would result in a total administration time of 2minutes.

If cardioplegia is to be administered retrograde, then the usual retrograde administration guideline should be followed i.e. monitoring the coronary sinus pressure and ensuring this does not exceed 40mmHg.

The initial flow rate for root administration is limited to 300 mL/min in larger patients.

In unusual circumstances, such as severe aortic incompetence, or when using retrograde, the delivery should be discussed with the surgeon and the amount determined in consultation.

Cardioplegia system pressures may be higher with increased flows, smaller root needles, and ostial delivery. These higher system pressures are not linearly related to root pressure, but it is still imperative that the surgeon visually monitor delivery.

24.2.7 Addition of Mannitol

For cases in which the patient is receiving del Nido cardioplegia, the perfusionist will administer 0.25 g/kg of mannitol (up to a maximum of 12.5 g) twice into the bypass circuit. The first dose is to be administered at the initiation of bypass and the second dose immediately preceding cross-clamp removal. If, however, ACP immediately precedes cross clamp removal then the second dose of Mannitol should be delayed until whole body perfusion has been re-established.

Below is a table to be used as a reference guide for del Nido and Mannitol doses for weight ranges.

Patient Weight (kg)	del Nido Dose (20 mL/kg)	20% Mannitol Dose (mL)
2	40	2.5 mL
2.5	50	3.1 mL
3	60	3.75 mL
4	80	5.0 mL
5	100	6.25 mL
7.5	150	9.375 mL
10	200	12.5 mL
15	300	18.75 mL
20	400	25 mL

25	500	31.25 mL
30	600	37.5 mL
50	1000	62.5 mL
75	1000	62.5 mL

24.3 Aortic Root Cardioplegia

Aortic root cardioplegia is used on all nearly all procedures for induction and maintenance, where the surgical procedure does not physically interfere with the technique.

24.4 Coronary Ostium Cardioplegia

A coronary ostium cardioplegia cannula is selected to deliver antegrade cardioplegia directly into the coronary ostia. This type of cardioplegia cannula is used on procedures for induction and maintenance where the surgical procedure physically interferes with the use of an aortic root coronary cannula and/ or where anatomy precludes the use of a retrograde (coronary sinus) cardioplegia cannula. Higher cardioplegia line pressures should be expected during administration of cardioplegia using this method. For information pertaining to expected cardioplegia delivery pressures see Section 10.3.

24.5 Retrograde Cardioplegia

This type of cardioplegia cannula is used to deliver retrograde cardioplegia via the coronary sinus. This type of cardioplegia cannula is used for induction and maintenance where aortic insufficiency and/or the surgical procedure preclude the use of an aortic root cardioplegia cannula.

During administration of retrograde cardioplegia it is imperative that the coronary sinus pressure is monitored and does not exceed 40mmHg. This is in order to prevent damage to this low pressure vessel.

24.6 Unusual Cardioplegia Delivery

Occasionally cardioplegia may be given following the commencement of Deep Hypothermic Circulatory Arrest (see Section 28.4).

If a particularly diminutive aorta exists, such as with hypoplastic left heart syndrome, bypass may be initiated with cannulation of a graft sewn onto the innominate artery. It may be necessary to administer cardioplegia via a leur port on this aortic cannula. For this to occur the following steps should be followed:

- Arterial blood pump stopped.
- Arterial and venous lines clamped.
- Large recirculation line opened and recirculation commenced.
- Surgeon should clip all head vessels and clamp the aorta to ensure that cardioplegia is delivered to the coronary vasculature.
- Commence cardioplegia delivery, ensuring that the combined blood and crystalloid flow do not exceed the recirculating blood pump flow.
- Once cardioplegia is completed full bypass, regional cerebral perfusion or DHCA may be embarked upon.

25 Haemofiltration during CPB

The use of haemofiltration during cardiopulmonary bypass should be considered when:

- Excessive circulating volume on bypass is present.
- A low haematocrit of less than 30% is recorded.
- The patient is hyperkalaemic.
- A COP <18mmHg is recorded.

Due to the haemofilter also being part of the cardioplegia circuit it is advisable, before commencing haemofiltration, to ascertain whether cardioplegia is to be given imminently. It would not be advisable to deliver high haematocrit blood to the coronary vasculature.

Two types of haemofiltration can be performed during CPB: Negative Balance Ultrafiltration and Zero Balance Ultrafiltration (ZBUF).

Negative balance ultrafiltration can be used when there is excessive volume in the reservoir, reduced haematocrit, or low COP. The removal of the filtrate helps to concentrate the circulating haematocrit.

Zero balance ultrafiltration would be used where the patient's potassium level is greater than 6mmol/L. Set volumes of 0.9% saline can be added to the circuit and then removed via the filter. This can be repeated to help lower the circulating potassium.

Whenever haemofiltration, or indeed cardioplegia, is being used arterial blood flow has now being re-directed away from the systemic circulation. The main arterial pump speed should be increased to compensate for this.

Care must be taken not to over-filter the patient i.e. increase the haematocrit excessively.

Before terminating bypass, flow through the haemofilter should be stopped.

The amount of filtrate in the waste canister should be recorded on the DMS. Any volume given during ZBUF must also be recorded.

During excessive haemofiltration ACT monitoring may need to be intensified as heparin will also be filtered from the circuit.

26 Cooling Technique

26.1 Perfusate Temperature and Temperature Gradient

During cooling do not exceed a 6°C temperature gradient between the perfusate and nasopharyngeal temperature, or a 4°C difference between the arterial and venous blood temperatures.

The target cooling temperature is obtained and maintained by keeping the perfusate at or just below the target temperature.

26.2 Deep Hypothermic Circulatory Arrest (DHCA) Cooling Technique

This should be carried out in conjunction with pH gas management strategy (see Section 15).

Perfusate temperature and temperature gradient management are as above. In cases where DHCA is being used a rectal temperature may have been inserted in conjunction with a nasopharyngeal temperature. This temperature should be considered when assessing adequacy and uniformity of cooling.

Should a temperature gradient in excess of 5°C arise between the rectal and nasopharyngeal temperatures titrate the patient with 0.5 - 2.0% isofluorane. If the cooling gradient persists, consult the anaesthetist for methods of therapeutic vasodilation.

Twenty minutes is the minimal amount time allowed to cool the patient to 18 -20°C.

When severe hypothermia is being employed consideration must be given to the patient's haematocrit, especially if bank blood is being used. At lower temperatures red blood cells are significantly less deformable (more so with bank blood) and may result in compromise to microcirculatory flow which would be exacerbated further with increased viscosity. Ideally a haematocrit just ≤ 30% is preferred.

27 Rewarming Technique

Rewarming is initiated at the request of the surgeon. Unless otherwise specified, the patient is rewarmed to a nasopharyngeal and/or rectal temperature of 36.3°C.

27.1 Perfusate Temperature and Temperature Gradient

During rewarming, maintain a 4- 6°C gradient between the nasopharyngeal or venous blood temperature and the water bath of the heater/cooler unit or a 4°C difference between the arterial and venous blood tempertaures. Maintenance of this gradient should result in an increase of 1°C increase every 3 - 5 mins.

Do not allow the perfusate temperature to exceed 37°C, and do not raise the water bath temperature of the heater/cooler unit over 38.5 °C.

When the nasopharyngeal temperature reaches 36.3°C, a water bath temperature of ≤37.7°C is usually enough to maintain this.

27.2 Topical Rewarming

Once the patient temperature rises above 30°C the Bair Hugger can be turned on. This should be set to 37°C.

27.3 Pharmacology During Rewarming

- $NaHCO_3$- When the patient reaches 32°C; Consideration may be given to administering $NaHCO_3$ to resolve excessive metabolic acidosis.
- $CaCl_2$- Maintain an ionized Ca++ level of approximately 0.8- 1.0 mmol/L until 15 - 20 mins after myocardial reperfusion. Correct the ionized Ca++ level to approximately 1.2 mmol/L 15 - 20 mins after myocardial reperfusion.

27.4 Colloid Administration during Rewarming

- PRBC- occasionally it may be necessary to administer blood upon rewarming. Blood may be required in circumstances where the predicted post-operative haematocrit will be insufficient to meet the patient's oxygen delivery requirements. In general a non-

hypoxic patient will come off bypass with a haematocrit of 30- 35%. A hypoxic patient will require a haematocrit of 40-45%. Be aware that, especially in patients <10 kg, administration of non-cell salvage machine washed PRBC's can significantly lower the perfusate ionised Ca++, and supplementation may be required.

- 20% Albumin- During bypass close attention should be given to the patient's colloid osmotic pressure (COP). On bypass a colloid osmotic pressure (pre MUF) should be >18mmHg. 20% Albumin should be administered if a COP is less than this.

28 Deep Hypothermic Circulatory Arrest Technique

Prior to commencement of circulatory arrest, if an active aortic root vent is in place make sure the surgeon is reminded of this. The instruction should be given for the root vent to be turned off in order to prevent the aorta being sucked flat and possible air entrainment into the arterial circulation.

28.1 Cooling

See section 26.2.

28.2 Blood Gas Management

The patient will be cooled with a pH Stat blood gas management strategy (see Section 15). Once the patient has reached 18°C hyperoxygenation with FiO_2 1.0 should be commenced after consultation with the surgeon. In order to ensure adequate cooling the patient should be maintained at 18°C for at least 5 minutes prior to commencement of DHCA.).

In order to assist in ensuring that cooling is adequate a venous blood gas can be taken. If the venous pO_2 is greater than 300 mmHg one may assume that the entire body is adequately cooled and is utilising very little oxygen.

28.3 Circuit Management

To ensure patient and circuit safety a number of steps must be taken:

- Slow down and then stop the arterial pump.
- Clamp the arterial line.
- Start Circulatory Arrest stop watch.
- Unclamp the membrane recirculation line.
- Clamp venous line when venous drainage has ceased (unless cardioplegia is to be given and venous drainage is required for venting the heart).
- Commence recirculation through the membrane recirculation line.
- Unless otherwise established, inform surgeon every 10 min of arrest time.
- During circulatory arrest, the perfusate should be recirculated at the temperature that circulatory arrest was commenced (usually 18°C).
- A recirculating perfusate sample should be taken for blood gas and electrolyte analysis. At this time the $PaCO_2$ should be kept between 35- 40 mmHg. The PaO_2 should be kept

at the lower end of the range guideline: 90- 150 mmHg. In order to maintain this consideration may be given to turning off gas flow.

28.4 Cardioplegia Administration following DHCA Commencement

If cardioplegia is to be given following the clamping of arterial line:

- Commence recirculation through the membrane recirculation line.
- Administer cardioplegia ensuring that the temperature of the cardioplegia is at least as cold as the systemic blood flow temperature.
- Administer cardioplegia ensuring that the combined blood and crystalloid cardioplegia flow rate does not exceed membrane recirculation line flow rate.
- Following completion of cardioplegia the venous line can be clamped once venous drainage has ceased.

28.5 Re-initiation and Rewarming

- CPB is re-instituted at the surgeon's request.
- Recirculation should be ceased, the membrane recirculation line closed, and the pump pressurised.
- The arterial line tubing clamp can be removed and flow rate should be increased gradually to refill the patient.
- Once established that flow can be safely commenced remove the tubing clamp on the venous line.
- Stop the circulatory arrest stop watch.
- When CPB is fully re-established, the untoward effects of global tissue acidosis, such as elevated Lactate level, should be monitored.
- Following a period of at least 5 minutes cold reperfusion and in consultation with the surgeon, rewarming can be initiated (see Section 27).
- As rewarming progresses the perfusionist should begin to haemoconcentrate the perfusate to the target Hct. PRBC's should be added if necessary (see Section 27.4).
- From this point onward, the conduct of perfusion does not differ remarkably from other CPB procedures.

29 Antegrade Cerebral Perfusion Technique

This procedure involves perfusion of the cerebral structures usually via an arterially cannulated graft sewn onto the innominate artery, and drainage via the venous cannulae.

Once the patient has been cooled to the required temperature (see Section 26) the remaining head vessels (usually left common carotid and left subclavian) will usually have clips applied to them.

If required, cardioplegia can now be given. This will either be into the aortic root or through the luer port on the aortic cannula (see Sections 24.1 and 24.4).

A further clip is then applied to the proximal innominate artery. The surgeon will then announce that the patient is on 'head only perfusion'. Simultaneously the perfusionist will reduce flow to a previously established amount.

Low flow antegrade cerebral perfusion is usually 30 - 50mL/kg/min. This flow will usually result in a right radial arterial line pressure of 30 - 40mmHg. Attention must also be given to the arterial line pressure, as the displayed arterial line pressure is representative of the highest possible pressure exerted on the cerebral vessels.

Unless previously established, it is essential that the lower body arrest time is recorded and the surgeon is informed of the time every 10 minutes.

During ACP FiO_2 should be maintained at 1.0. This should be reduced to 0.21 just prior to reperfusion.

For procedures requiring ACP bilateral NIRS probes should be applied to the child's head. This is to monitor for differential cerebral perfusion which may be representative of anatomical variance to the circle of Willis. If this does become apparent then it is essential that this is communicated to the team.

Ensure the patient has a right radial and lower body arterial line inserted to enable accurate monitoring of pressures in the upper and lower body.

29.1 Lower body Perfusion

Occasionally during low flow antegrade cerebral perfusion the surgeon may attempt to, or intermittently perfuse the lower body. This involves placing a Y circuit into the arterial line. Prior to the procedure this possibility should be discussed with the surgeon so the appropriate Y circuit can be given to the scrub staff.

During separate upper and lower body perfusion, if possible the same size cannula should be used in order to reduce the chance of preferential flow to one of the separately perfused vascular beds.

Ensure the patient has a right radial and lower body arterial line inserted to enable accurate monitoring of pressures in the upper and lower body.

29.2 Myocardial Perfusion

Occasionally during low flow antegrade cerebral perfusion the surgeon may continually perfuse the coronary arteries. This technique would be dependent upon the size of the aorta. If the aorta is particularly small an olive tipped cannula, Y'ed from the arterial line, may be inserted into the bifurcated aorta, snared, and blood flow continually ran in via the main blood pump.

With the 4 mm olive tip cannula and the 8 Fr arterial cannula both "Y" ed from the one arterial line, the flow ratio is about 3.4: 1, i.e. there is 3.4 times the volume passing through the 8 Fr cannula than the olive tip. This flow should be fairly constant provided that the blood pressure is the same in both areas of the body.

If the aorta is larger in size a cardioplegia spike may be inserted into the aorta and blood continually ran in using the blood cardioplegia pump.

30 Carbon Dioxide (CO_2) Insufflation

CO_2 insufflation into the operative field is utilised at the request of the consultant surgeon. CO_2 flow rate is usually set at 3L/min. If this presents too great a challenge for gas management (i.e. in cases of excessive sucker usage) then a minimum strategy of 0.5 mL/min per mL of the maximum pump flow for the patient (e.g. Max pump flow: 2L/min, CO_2 flow 1L/min) may be used.

CO_2 is delivered via sterile tubing containing a gas filter and ideally must be clearly distinguishable from the pump suction tubing.

CO_2 insufflation may be used only in conjunction with continuous in-line PCO_2 monitoring.

31 Termination of CPB

Cardiopulmonary bypass should be terminated at the request of the surgeon.

Prior to the termination of bypass the perfusionist should ensure that:

- All purge lines and the sampling manifold should be turned off.
- The patient has attained a nasopharyngeal temperature above 36°C for several minutes.
- There is adequate volume in the venous reservoir.
- CPB circuit volatile anaesthetic gas is turned off.
- MUF pump is not circulating.
- Confirm with the anaesthetist that the patient is ventilated.
- The anaesthetist is prepared for the termination of bypass.

Only when the perfusionist is satisfied that all checks are complete should the termination of bypass be implemented:

- Partially occlude the venous line restricting blood return to the pump. This will allow filling the heart by raising venous pressure.
- As the venous line is occluded, arterial flow is manipulated to maintain safe reservoir levels. Additional fluid may need to be added to reservoir.
- Arterial pump flow is reduced.
- Once the heart is filled and ejecting, the pump flow is reduced to 1/2 flow and this is communicated to the surgeon.
- At the request of the surgeon flow will be reduced further by applying further restriction to the venous line and reducing arterial pump speed further.
- Once flow has been reduced to 1/4 flow and adequate filling is maintained the request will usually be made to cease bypass.
- The venous line is clamped and the pump stopped.
- Announce to the surgeon/anaesthetist that the patient is “Off Bypass”.
- Once off bypass the FiO_2 should be turned to 0.21 and sweep flow adjusted to baseline pre-bypass rates.

- Upon the successful termination of bypass further filling may be requested by the surgeon or anaesthetist.
- The perfusionist must be aware that at times the aortic root vent may still be being used following termination of bypass. In such circumstances the arterial pump flow rate should match the vent root rate in order to prevent patient exsanguination.
- Once stable the surgeon will request the commencement of MUF.

32 Modified Ultrafiltration (MUF)

MUF is a modification of conventional ultrafiltration where the patient undergoes ultrafiltration immediately after the termination of CPB allowing the red blood cells and plasma proteins remaining in the extracorporeal circuit to be returned to the patient while simultaneously removing excess water and ameliorating the inflammatory response by removing vasoactive materials and mediators of inflammation.

During the MUF period the anaethetist will administer FFP and Cryoprecipitate to the patient via an access line of the anaethetist's choice. The perfusionist and the anaesthetist will monitor Ca++ levels with routine blood gas samples to maintain adequate ionised Ca++ levels. Platelets should not ge administered during the MUF period

32.1 Indication for MUF

From a blood management perspective the perfusionist should be prepared to conduct MUF on all patients, although the benefits are more widely reported in infants and younger children.

The integrated cardioplegia hemofiltration in all circuits is capable of being used for cardioplegia delivery, conventional haemoconcentration, MUF, and circuit volume salvage following MUF.

32.2 MUF Initiation, and MUF Technique

- The patient must remain heparinised while MUF is taking place.
- CPB is terminated in the usual manner with clamps placed on both the venous and arterial lines (arterial line at perfusionist's discretion).
- The venous line clamp must between the venous reservoir and the junction of the MUF circuit entry, thus permitting blood flow to enter the venous line from the cardioplegia/ MUF circuit, and progress up the venous line.
- MUF should be commenced upon the surgeon's request.
- Ensure that the negative arterial pressure alarm is activated. During MUF, manipulation of the aorta or heart can cause the arterial cannula to become inadvertently stuck against the aortic wall causing cavitation. Cavitation is particularly dangerous at higher flow rates. If air is visualised, immediately discontinue MUF and inform the surgeon.
- Ensure that cardioplegia/ MUF heat exchanger temperature is set at 38°C.
- If applied, remove the clamp on the arterial line.
- Request surgeon's assurance that the lines on the table are air free.

- The perfusionist must consult with the surgeon and anesthesiologist to determine the target filling pressure necessary to achieve hemodynamic stability.
- To initiate MUF, the MUF (cardioplegia blood) pump, once unslaved, is turned on and increased up to no more than 10- 15% of full flow, but not exceeding the maximum flow rate for the haemofilter. Blood is now being drawn down the arterial line through the haemofilter and back up the venous line.
- Once flow is established the clamp should be removed from the haemofilter effluent line to commence haemofiltration with the suction usually set at -150mmHg.
- If filling pressures deviate from the desired range, fluid can be added to the patient by turning on the arterial blood pump and thus adding fluid from the venous reservoir.
- If for some reason MUF must be emergently discontinued always ensure that the effluent line is reclamped.
- MUF should continue for approximately 10 minutes or terminated because:
  - There are no red cells left in the extracorporeal circuit to be salvaged.
  - The target Hct has been achieved.
  - The patient becomes unstable.
  - Air is spotted in the table lines.

32.3 Termination of MUF

- Clamp the haemofilter effluent line.
- Leave MUF pump running in order to ensure the remaining high Hct blood within the circuit is transfused to the patient.
- Stop the MUF and the arterial pump.
- Clamp arterial line.
- Inform the surgeon that MUF has ceased.
- The patient may still require further transfusion from the pump. The perfusionist must be prepared to transfuse further volume until decannulation is complete.
- Make sure all the pertinent data was recorded on the perfusion record.
- The sieving coefficient of heparin is approximately 0.2. Consequently, MUF may increase the patient heparin concentration, and the appropriate protamine dose may be higher than expected.

33 Transfusion Post CPB

Following termination of CPB the surgeon or anaesthetist may request volume be transfused from the CPB circuit into the patient.

33.1 Transfusion into arterial circulation.

For volume to be transfused into the arterial circulation:

- Ensure circuit is air free.
- If arterial line is clamped ensure circuit is positively pressurised.
- Remove arterial clamp.
- Transfuse volume till desired filling pressure is reached.
- Turn off arterial blood pump.
- Reclamp arterial line.

33.2 Transfusion into venous circulation.

Occasionally the surgeon may remove the arterial cannula prior to the venous cannula being removed. If this occurs it may be necessary to transfuse volume up the venous line into the patient:

- Ensure venous line is air free.
- Ensure arterial line is clamped.
- The venous line clamp must between the venous reservoir and the junction of the MUF circuit entry, thus permitting blood flow to enter the venous line from the cardioplegia/ MUF circuit, and progress up the venous line.
- Open the membrane recirculation line.
- Commence recirculation through the membrane recirculation line by turning on the blood pump.
- Initiate flow to the patient by turning on the MUF (cardioplegia blood) pump.
- Ensure that the MUF pump flow rate does not exceed the arterial blood pump flow rate.
- Transfuse untill desired filling pressure is achieved.
- To cease turn off MUF pump.

34 Post Bypass

Once no further transfusion is required:

- The arterial and venous lines can be clamped (at this stage it is preferable to clamp the venous line at the patient side of the cardioplegia entry port into the venous line).
- The membrane recirculation line is opened and recirculation can be commenced by turning on the arterial blood pump.
- Due to the position of the venous clamp it is now possible to also recirculate through the cardioplegia/ MUF circuit. Ensure that the cardioplegia blood/ MUF pump speed does not exceed the arterial blood pump speed.

- If excess volume is present in the venous reservoir the clamp can be removed from the haemofilter effluent line and haemoconcentration commenced.
- The surgeon will ask the anaesthetist to administer protamine. The anaesthetist should inform the perfusionist that protamine is being infused. Once half of the protamine has been infused the cardiotomy suction must then be turned off and the surgeon informed.
- Once the surgeon hands the lines back to the perfusionist (or at his request prior to the line being handed back) the residual volume in the bypass circuit can be either sent to the cell salvage machine or concentrated further and then pumped into a retransfusion bag. The bag is then appropriately labeled (see Cell Salvage practice guideline http://webapps.schn.health.nsw.gov.au/epolicy/policy/4426) and handed to the anaesthetist for retransfusion.
- At times it may be deemed preferable to process the residual pump volume through a cell salvage device. This can be done prior to the surgeon handing the lines back providing the circuit remains primed with crystalloid. The perfusionist must be aware that cell salvage machine processing results in the washing out of any clotting factors present.
- The pump can then be stripped down, whilst in theatre, and bagged in a thick walled clinical waste bag. The pump can then be disconnected, and wheeled into the pump room.

35 Cleaning and Disposal of Equipment

- The perfusionist is required to remove all items of perfusion equipment from the operating theatre.
- The heart lung machine and all items of equipment should be thoroughly cleaned with diluted Viraclean.
- Any faults should be noted and logged with appropriate personnel notified. Any faults should be rectified as soon as possible.
- Following cleaning universal pump components should be placed on the pump ready for the next case.
- Always ensure that the pump is plugged in to ensure that the CDI500 battery remains charged.

36 Left Heart Bypass

36.1 Left Heart Bypass Cannulation

For certain procedures not requiring full CPB, left heart bypass may be required. Whilst consideration should be given to using a 'modified ECMO setup' the possibility of the need to convert to full bypass and the possibility of the requirement to scavenge and retransfuse large amounts of blood, would make the use of the HLM the default option.

Cannulation for left heart bypass is usually:

- Left atrium to femoral artery.
- Left atrium to descending aorta.

36.2 Left Heart Bypass Management

- Standard CPB setup, prime and anticoagulation recommendations apply.
- A femoral arterial line is necessary to monitor perfusion pressure distal to the clamped aorta.
- A right radial arterial line is necessary to monitor perfusion pressure proximal clamped aorta.
- Upon commencement of left heart bypass an adequate restriction must be placed on the venous line in order to prevent excessive drainage of the patient.
- Patient flow should gradually be increased to approximately 2/3 of full flow with the overall aim of maintaining similar patient pressures proximal and distal to the clamps.
- Flow should be increased, or venous line restriction, reduced in order to maintain appropriate filling/ pressures.

36.3 Left Heart Bypass using ECMO circuit

Considerations:

- Due to the relatively diminutive circuit size minimal heparinisation (100 units/kg) may be requested.
- Cortiva coated components should be used if available.
- An ACT > 200 seconds is sufficient for left heart bypass cases.
- With this technique, the patient becomes the ‘venous reservoir’. Of critical importance is the ability of the anesthesiologist to maintain patient volume load.
- A femoral arterial line is necessary to monitor perfusion pressure distal to the clamped aorta.
- A right radial arterial line is necessary to monitor perfusion pressure proximal clamped aorta.

36.3.1 Left Heart Bypass ECMO Circuit Equipment

For left heart bypass an ECMO trolley/ circuit appropriate for the patients predicted flow rate should be retrieved. For information regarding circuit size see:
http://webapps.schn.health.nsw.gov.au/epolicy/policy/3124

For the provision of left heart bypass, ensure trolley contains:

- X2 Levitronix Consoles.
- X2 Levitronix remote pump heads.
- X1 appropriate sized flow probe.

Disposable equipment required:

- Appropriate sized Levitronix pump head.
  - For flows < 1.7 L/min, use the 1/4" Levitronix pump head.
  - For flows > 1.7 L/min, use the 3/8" Levitronix pump head.
- Appropriate sized ECMO pack.
- 'Bits and Bobs' pack containing lengths of Cortiva coated 1/4" and 3/8" tubing.

36.3.2 Circuit Setup and Prime

- If the ECMO circuit is not pre-primed then its should be primed as per ECMO guideline http://webapps.schn.health.nsw.gov.au/epolicy/policy/3124
- Consideration should be given to clamping proximal to the haemofilter and not inserting CDI500 shunt sensor.
- Ensure that the ECMO heater is on in order to maintain an adequate patient temperature. If the patient was to cool excessively fibrillation could occur.

36.3.3 Initiation

- Prior to initiation of left heart bypass the surgeon and perfusionist should both ensure that the inlet and outlet lines of the circuit are connected to the appropriate cannula.
- Initiation of left heart bypass is made at the surgeon's request.
- The inlet clamp should be released first, 1000 RPM be generated on the pump head, then the pump outlet clamp removed.
- A visual assessment should then be made ensuring that blood is progressing through the circuit in the desired direction.
- Flow can then be increased to the desired flow.

36.4 Perfusion Parameters

- Prior to placement of the aortic clamps the generated blood flow should maintain baseline pressures in both upper body and lower body arterial lines. This will usually be approximately '2/3 full flow' (see Section 3).
- After placement of the aortic clamps adjust the blood flow rate or have the anesthesiologist transfuse volume to maintain an age appropriate proximal mean arterial pressure.
- NIRS probes may be applied to the head and lower body to guide adequacy of perfusion monitoring.
- ACT should be monitored after initiation of left heart bypass and then every 30 minutes.

36.5 Termination

- Termination of left heart bypass is made at the surgeon's request.
- Flow will usually be reduced gradually.
- If using an ECMO circuit no capacitance exists in the circuit, so any additional filling will be via anaesthesia.

37 Unusual Arterial Cannulation

37.1 Graft Cannulation on Innominate Artery

For certain procedures, most commonly the Norwood Procedure, and usually due to a diminutive aorta, the surgeon may sew a Dacron graft onto the innominate artery and then cannulate this graft directly. In essence the management of this does not immediately differ from standard aortic Cannulation. Considerations include:

- If low flow antegrade cerebral perfusion is to be used a right radial arterial line is essential, unless the patient has a right sided aortic arch, then a left radial arterial line would be required
- If the innominate graft and patent arterial duct are to be cannulated, or separate upper and lower body perfusion will be required, the appropriate sized bifurcated arterial line tubing set must be selected (see Section 37.2 below).
- If cardioplegia is to be used, and the aorta is too small to use a cardioplegia needle, an aortic cannula with a luer connector must be selected to enable the cardioplegia line to be connected to the aortic cannula (see Section 24.2).

37.2 Interrupted Aortic Arch Arterial Cannulation

Patients with interrupted aortic arch require arterial cannulation both proximal and distal to the point of interruption to ensure adequate perfusion. This will require use of the bifurcated arterial line tubing set. Considerations include:

- If possible, the two arterial cannula should be equal in size to facilitate equal distribution of flow to the upper and lower body. Typically, the proximal arterial cannulation site is the aortic root. The distal arterial cannulation site is just distal to the interruption or in the patent ductus arteriosus. .
- After the repair has been completed, adequate perfusion necessitates only aortic root cannulation. The perfusionist must make certain that the arterial cannula used is large enough to accommodate the maximal blood flow rate.

38 Management of Jehovah's Witness Patients

Jehovah's Witnesses are a religious group whose interpretation of the Bible precludes transfusion of homologous blood products or of autologous blood products that have been isolated from the body.

The medical team has a legal responsibility to ensure that the child comes to no harm and can transfuse the child with blood products if they believe the child will be harmed by not transfusing him/ her.

The task of the cardiac surgical team is to formulate an overall medical strategy that may reduce the risk of morbidity and mortality. The strategy can include the following:

- Reduce the risk of patient hemorrhage. For example, discontinue platelet inhibiting drugs, and anticoagulants preoperatively.

- In consultation with the hematologist, begin a pre-surgical regimen of erythropoietin, FeSO4, and/or folate to increase the patient's red blood cell count.
- Use antifibrinolytic drugs such as aprotinin or tranexamic acid to reduce intra-operative and post-operative bleeding (see Section 6).
- Minimize number and amount of blood samples.
- Ascertain if the patient's/ parent's belief precludes albumin, FFP, cryoprecipitate, and platelet administration.
- Integrate cell salvage equipment into the extra-corporeal circuit ensuring that continuity of blood with the patient is not breached.
- Minimize the prime volume of the extracorporeal circuit.
- Use retrograde autologous priming to reduce haemodilution further (see section 14.1).
- Use ultrafiltration during and modified ultrafiltration post bypass.
- Consider the use of VAVD if this will result in the use of a smaller diameter venous line (see Section 16).

39 Sickle Cell Disease

Care should be taken to maintain normal temperature, hydration and positioning to avoid blood stasis, thereby minimising sickling. CPB should not be undergone without input from the haematologist. It is generally considered safe to undergo CPB where HbS <20%. Where HbS >20% and < 40% the following should be considered:

- Maintain adequate arterial oxygen tension.
- Avoidance of low output states.
- Prevent low mixed venous oxygen saturations
- Consider preoperative or intraoperative exchange transfusion.
- Avoid right shift of oxygen dissociation curve- aggressively treat acidosis.
- Avoid sickling in coronary arteries by flushing haemoglobin S out with crystalloid cardioplegia or blood cardioplegia rich in haemoglobin A.
- Avoid mechanical valves where possible.
- Minimise cardiotomy suction and venting.
- Avoid hypothermia.

Where HbS >40% elective surgery should not take place without exchange transfusion. The blood removed can be centrifuged to allow plasma and platelets and clotting factors to be returned.

40 Cold Agglutinins CPB Management

Immunoglobin IgM autoantibodies to red blood cells can cause catastrophic haemaglutination, microvascular thrombosis or haemolysis. Undetected cold agglutinins may present in the cardiopulmonary circuit as a separation of blood cells and plasma. Symptoms related to cold agglutinins may present as acrocyanosis, Reynaud's Phenomena, haemoglobinura, jaundice, and pallor.

The cold agglutinin test performed prior to surgery yields two results: a titer and thermal amplitude. Decreasing the titer and/ or maintaining the blood temperature above the thermal amplitude will prevent the blood from agglutination.

To prevent the agglutination of blood, a number of techniques may be employed depending on the severity of the condition and the cardiac lesion being repaired:

- Postpone case if possible and retest in two weeks. These antibodies are typically caused by a viral infection and tend to disappear over time.
- Maintain blood and core temperature above thermal amplitude. A range in thermal amplitude will be reported and within this range is where agglutination occurs.
- Consider utilising fibrillation or avoid arresting the heart if possible.
- Avoid topical application of ice solution to heart.
- Consider bicaval cannulation to isolate the heart.
- If DHCA is required:
    - Consider high dose IgG administration (Rituximab). This can result in an 8 fold decrease in titers.
    - Suggest plasmapheresis with FFP and crystalloids the night before and morning of surgery, to lower titers as well.
    - Steroid administarion.
- Consider the use of crystalloid cardioplegia.
    - Begin with warm induction (35°C) and then switch to desired temperature.
    - Vent right atrium to the cells saver.
    - Give warm shot of crystalloid cardioplegia prior to removal of cross clamp.

41 Intra-Aortic Balloon Pumping

Intra-aortic balloon pumping (IABA) is rarely instigated at CHW, and would only be done so at the request of a consultant surgeon.

A Datascope device is available in Westmead Adult Hospital perfusion department. It should be noted however that the efficacy of IABA in the paediatric population is controversial and, as such, no balloons are held in stock.

42 Emergency Management

42.1 Massive Air Embolism

- Turn off pump immediately and clamp arterial and venous lines.
- Place patient in steep Trendelenberg position.
- Remove Aortic Cannula from ascending aorta.
- Determine cause of accident and correct.
- After purging air and refilling CPB systemic flow line, insert arterial cannula into SVC above a point where a vascular clamp can be applied. For bicaval cannulation it is possible to attach systemic tubing to snared SVC cannula.
- Begin retrograde perfusion with hypothermia at 30-50mL/kg/min for 1-3 minutes or until no more froth is observed exiting opened aorta.
- Compress carotid arteries during later phase to purge air retrograde through the vertebral system.
- Consider pharmacological management including:
  - phenobarbital
  - thiopentone
  - steroids
  - mannitol
- Discontinue retrograde perfusion and restart antegrade bypass with 100% oxygen.
- Administer vasopressors to maintain high perfusion pressures.
- Post-procedure consider transfer of patient to hyperbaric oxygen therapy center. If hyperbaric therapy is required switch board at Prince of Wales Hospital, Sydney should be contacted; and the on-call medical officer on call for hyperbaric medicine requested.

42.2 Power Failure

- Inform surgeon.
- Obtain assistance.
- Attempt to trace fault.
- Establish estimated time of power return.
- Prepare to initiate manual operation of pump in case of battery failure.
- See section 42.6 for management of heater cooler failure.

42.3 Roller Pump Module Failure

- Upon roller pump module failure clamp the arterial and venous line to prevent patient exsanguination.
- Inform surgeon.
- Reduce the RPM setting to prevent tubing rupture should the pump module restart.

- Ensure that a false indication from the safety monitors is not the source of pump shut down.
- Ensure that the pump base power cord is plugged in and that the plump base power switch is turned on.
- Switch the pump base power cord to another AC power outlet.
- Transfer to back up roller pump.
    - Back up roller pump can be plugged directly into the mains in which case it will run in free mode.
- Hand crank the console if a backup module is not immediately available.

42.4 Air in Arterial Line (not patient)

- Inform surgeon.
- Stop arterial pump.
- Clamp venous line.
- Obtain assistance.
- Check for cause of air and rectify if possible.
- If necessary reprime circuit by initiating internal recirculation via recirculation lines.
- It may be necessary to get surgical assistance in removing distal circuit air by cutting arterial line proximal to aortic cannula, priming arterial line antegrade and reconnecting arterial line once air free.
- The arterial line can also be reprimed retrogradely from the patient by removing the clamp from the large recirculation line and permitting fluid to drain from the patient into the reservoir.
- Check circuit for any remaining air.
- Recirculation lines should be closed and pump pressurised.
- Inform surgeon that bypass can be recommenced, on surgeons instruction recommence bypass.
- Observe closely for any signs of air entrainment.

42.5 Oxygenator Failure

An oxygenator failure may manifest with a falling arterial PO_2 or falling venous saturations in the presence of 100% FIO_2, and flows at normal to high cardiac index and adequate anaesthesia.

A physical oxygen delivery problem should be ruled out. The simplest way of doing this is to use an oxygen cylinder, connected directly to the gas inlet port of the oxygenator. A blood gas should be rechecked, whilst waiting for the result any colour change of post oxygenator blood should be observed for.

Observation should also be made for any signs of a blood phase to gas phase leak.

The surgeon and anaesthetist should be notified of the problem immediately. It should first be ascertained whether the patient can be safely separated from bypass, if not and

oxygenation is being compromised emergency replacement of the oxygenator should be prepared for:

- Notify surgeon and anaesthetist of problem; and seek qualified assistance.
- Turn FiO_2 to 1.0.
- Initiate further cooling if possible.
- Turn off water flow to heat exchanger and disconnect water lines.
- Remove monitoring/ sampling line form oxygenator outlet.
- Remove recirculation line, which exits the top of the oxygenator, from the top of the reservoir.
- If present remove arterial line pressure monitoring from oxygenator outlet.
- Remove oxygen delivery line.
- Clamp venous line, turn off arterial blood pump and clamp arterial line.
- Double clamp oxygenator inlet leaving at least 1.5” between clamps.
- Double clamp oxygenator outlet leaving at least 1.5” between clamps.
- After swabbing, using sterile shears, cut between double clamps on oxygenator inlet and outlet.
- Attach pump boot tubing to inlet of new oxygenator.
- Attach oxygenator outlet tubing to new oxygenator.
- Attach monitoring/ sampling line form to new oxygenator outlet.
- Attach purge line from the top of the new oxygenator to the top of the reservoir.
- Attach arterial line pressure monitoring to oxygenator outlet.
- Attach gas tubing to oxygenator.
- Remove clamps from all recirculation lines and oxygenator inlet/ outlet tubing, (ensure that a clamp remains on arterial line just distal to ‘Y’ recirculation line to reservoir).
- After verifying sufficient volume in venous reservoir, turn on arterial blood pump to slowly prime the oxygenator.
- Ensure no air is present on proximal side of distal arterial line clamp.
- When satisfied device and circuit are air free, stop the blood pump close recirculation line and pressurise pump.
- Inform surgeon that bypass can be recommenced, on surgeons instruction recommence bypass.
- Once bypass is safely reestablished the water lines can be reconnected and water recirculated.

42.6 Heat Exchanger Failure

Although extremely rare, the most common reason for a heat exchanger to fail is a communication between the water and blood phase. Signs of a leak are:

- Unexpected rise in reservoir volume.
- Rise in potassium level.
- Decreasing pH.

- Decreasing hematocrit.
- Haemolysis with hemoglobinuria.
- Visible blood in heater cooler water lines.

Whether a water to blood communication is present in the oxygenator heat exchanger, or the cardioplegia heat exchanger, the water flow should be stopped immediately and the surgeon and anaesthetist informed.

If the leak is within the oxygenator the oxygenator should be replaced as per section 42.5.

If the leak is within the cardioplegia heat exchanger:

- After water is turned off, turn off cardioplegia/ MUF blood pump.
- Double clamp tubing proximal and distal to device leaving at least 1.5” between clamps.
- Swab tubing and, using sterile shears, cut between clamps in proximal and distal location.
- Join tubing together using a 3/16” leur straight connector (a pressure monitoring line can be connected to the leur port should further cardioplegia be given without a new heat exchanger).
- If further cardioplegia is required consideration can be given to inserting another heat exchanger or simply cooling the patient to the temperature the cardioplegia is to be given at thus cooling cardioplegia blood temperature.

42.7 Heater/ Cooler Failure

- Check water lines for kinks or obstructions.
- If the heater/cooler is deemed to be defective switch to a backup device.
- If a backup HCU is not available, consider using the ECMO heater cooler, or any of the ECMO heaters should warming only be required.
- In the unlikely event of the failure of both heater cooler units, the following procedure should be considered as a rescue system.
    - The water lines exiting from the HCU should be double clamped and cut between these clamps.
    - A bucket should be retrieved and filled with either cold or very hot water as required.
    - One end of the cut tubing should either be connected to a centrifugal pump, or be connected to a ½’ pump boot and be passed through the raceway of a spare roller pump module and the occlusion set to achieve forward flow.
    - Both ends of the cut tubing leading to the oxygenator should now be placed into the bucket and kept below the level of the water.
    - The roller pump is now started, very slowly at first monitoring the temperature of the arterial blood carefully.
    - The temperature of the water and the speed of flow should be adjusted to maintain the perfusate temperature as desired. Very low flows will be required to achieve large swings in temperature of the perfusate. Care must be taken to achieve this slowly.

- Further assistance will be required to retrieve hot water (Zip system in the coffee room) or ice from the kitchens.

42.8 Hard Shell Reservoir Failure

The use of an integral cardiotomy reservoir, involves firstly terminating bypass due to interruption to the venous drainage, while the cardiotomy is changed.

The surgeon and anaesthetist should be notified of the problem immediately. It should first be ascertained whether the patient can be safely separated from bypass, if not emergency replacement of the reservoir should be prepared for:

- Notify surgeon and anaesthetist of problem; and seek qualified assistance.
- Turn FiO_2 to 1.0.
- Initiate further cooling if possible.
- The venous line is clamped.
- The arterial pump is switched off.
- The arterial line clamped and all suckers are switched off.
- The following are then double clamped:
  - The outlet from the reservoir to the pump.
  - The venous line to the reservoir.
- These lines are then cut, while suction and recirculation lines, together with the fluid giving set can be removed and kept sterile.
- The venous inlet, reservoir outlet, suction line and recirculation line are all reattached.
- Volume is added to the newly established cardiotomy.
- The clamps on the reservoir outlet are removed and any bubbles that have entered are removed.
- Recirculation lines should be closed and pump pressurised.
- Inform surgeon that bypass can be recommenced, on surgeons instruction recommence bypass.
- Volume from failed reservoir can be transfused to the new reservoir.

42.9 Pump Boot Rupture

- Inform surgeon.
- Stop arterial pump.
- Clamp arterial and venous lines.
- Obtain assistance.
- Clamp outlet from venous reservoir and inlet to oxygenator.
- Replace pump boot using appropriate tubing and connectors.
- Remove clamp from reservoir outlet, permitting the pump boot to slowly prime in an antegrade manner.
- Insert new boot into pump.
- Ensure circuit is air free by recirculating via recirculation lines.

- Check occlusion.
- Check circuit for any remaining air
- Recirculation lines should be closed and pump pressurised.
- Inform surgeon that bypass can be recommenced, on surgeons instruction recommence bypass.

43 Emergency Equipment Checking

Within the theatre 5 pump room is a backup roller pump and backup oxygen/air cylinders. These are situated under the main computer desk. These should be checked once per week and this documented on the perfusion checks spreadsheet located in G/APPS/Admin/Perfusion.

44 Incident and Device Reporting

- The perfusionist will voice any concerns to the surgical team dealing with device failure or any occurrence out of the ordinary that may have a negative impact on the patient as soon as the problem becomes apparent.
- The perfusionist will voice any concerns to the surgical team if any observed behavior may result in a negative outcome for the patient or result in a team member not being able to function at an acceptable level.
- The chief perfusionist shall be notified as soon as possible (within 24 hrs) of an incident or device failure.
- The circuit or device shall be saved until released by the chief perfusionist.
- A hospital incident form must be filled in after an incident occurrence, as should a local device failure form. Consideration should be given to reporting to the ANZCP PIRS database.

45 References

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