

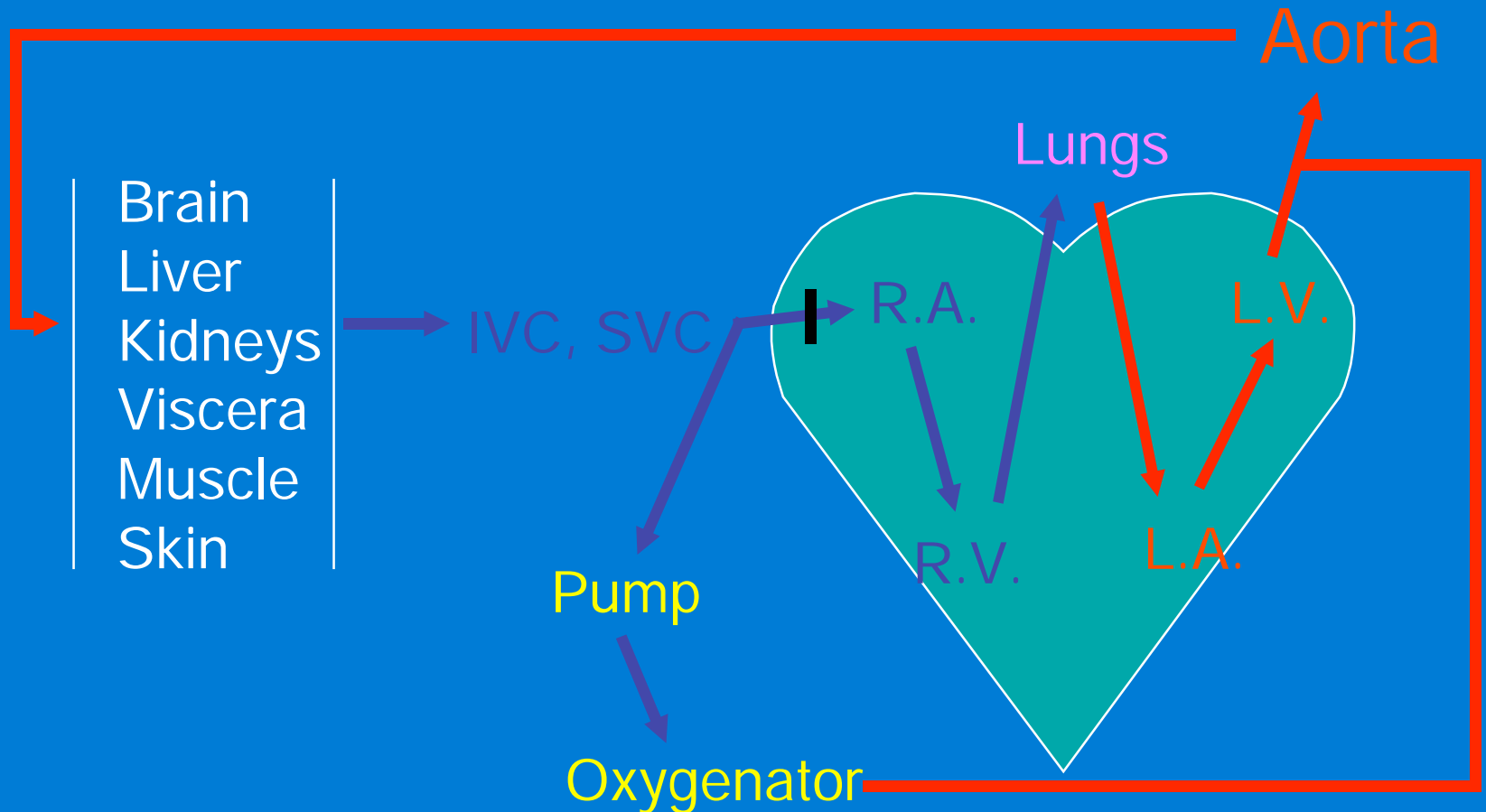


Going on Bypass

What happens before, during and after CPB.

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Circulation



Membrane Oxygenator



Arterial Filter

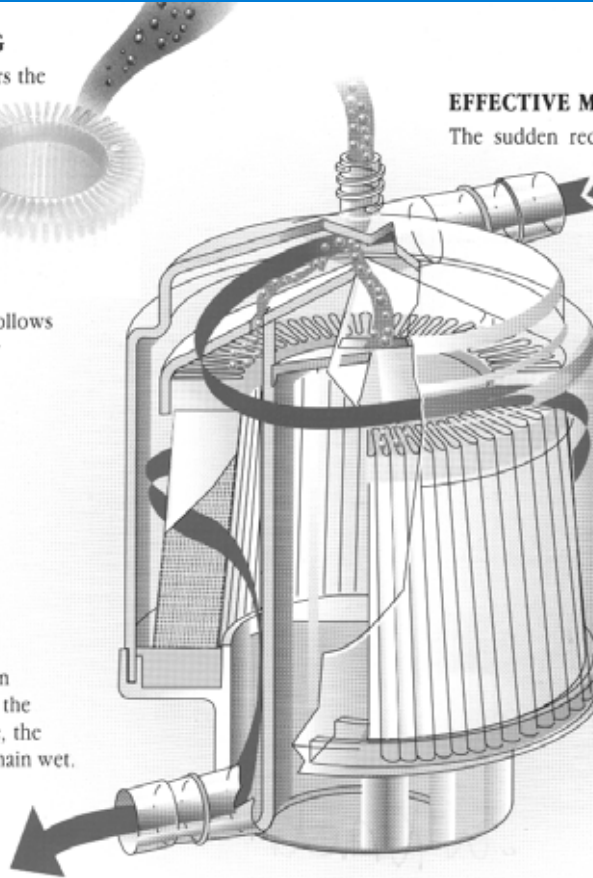
EASY DEBUBBLING

With conventional filters the most difficult bubbles to remove are those trapped under the upper potting. In the Dideco Micro series of filters, the polyurethane seal follows each pleat, allowing for efficient debubbling.



EFFECTIVE MICRO AIR REMOVAL

The sudden reduction of blood velocity at the upper portion of the filter, combined with the orientation of the inlet connectors, allows microbubbles to rise easily to the top of the filter. The large filter area assures effective filtration, resulting in a low pressure drop and consequently a low incidence of blood damage.



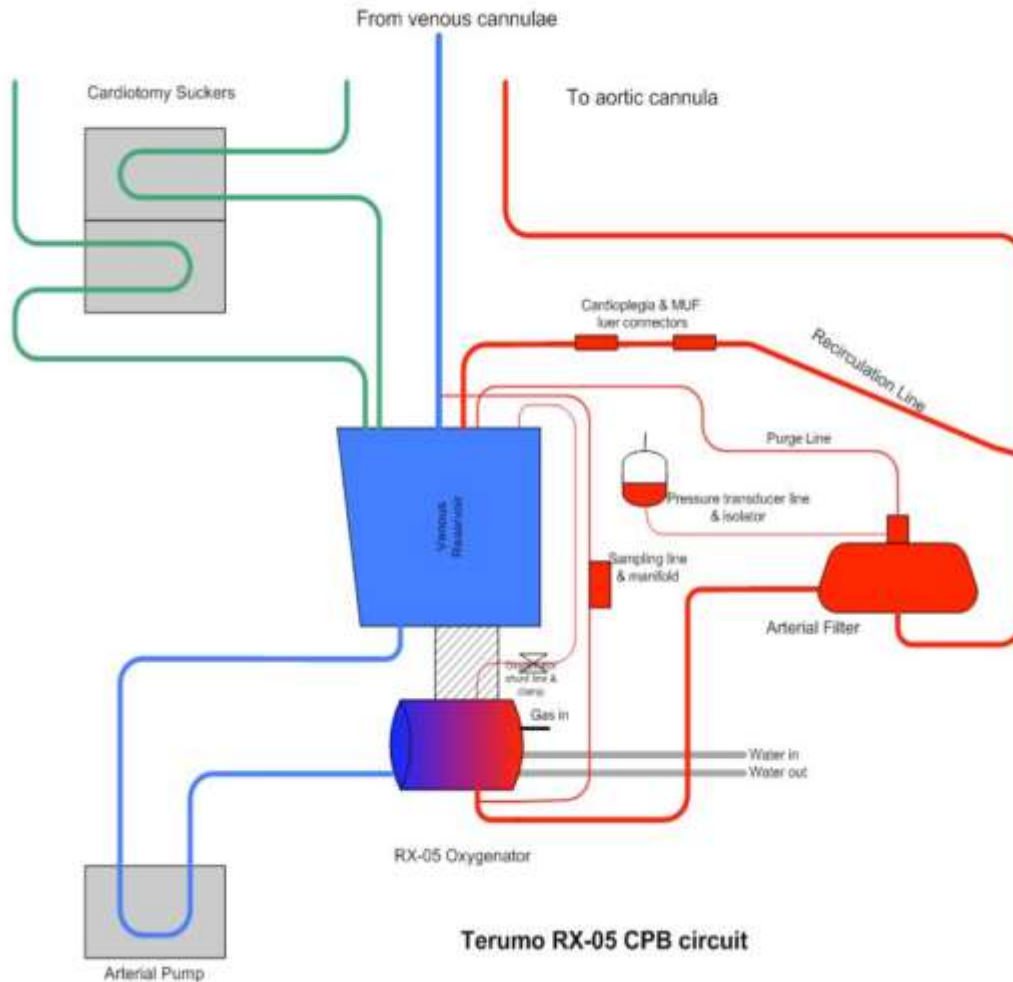
SAFE AGAINST MACRO AIR

The high inlet/outlet volume ratio prolongs the reaction time. The filter allows air to pass through it only when it is dry. This means that the higher the inlet volume, the longer the filter will remain wet.

HIGH VISIBILITY

The filter is totally clear. No bubble will remain undetected.

Bypass Circuit



Cardio-pulmonary Bypass Prime

Aim: to have enough fluid volume to prime the circuit, whilst not overdiluting the total haemoglobin pool.

In paediatric CPB, size is important

Weight(kg)	Blood Volume (ml)	Prime Volume (ml)	Ratio
2	200	400-500	>2 : 1
4	400	500	1.5 : 1
6	600	600	1 : 1
16	1300	1100	.85 : 1
70	4900	1600	.32 : 1

Cardio-pulmonary Bypass Prime

- At RCH:
- * Tailored individually.
 - * Aim for a final, combined Hb (ie Patient + pump) of 8-9 gm/dL.
 - * Computer generated.

3 Basic Types of Prime:

1. Using fresh heparinised blood.
2. Using fresh citrated blood or packed cells.
3. Using no blood.

Heparinised Blood Prime

- * Fresh - ;less than 24 hrs since donation
- * Anticoagulated with 25mg of heparin
- * "Normal " K, H, Lactate. Na, etc.
- * High yield of robust RBCs.

In practice:

- * 1/2 or 1 unit of blood + crystalloid.
- * No citrate \therefore no NaHCO_3 , \therefore "normal" Na^+
- * Lower dextrose
- * for patients < 6 kg
- * priming volume 400 - 500 mls

Fresh Blood Prime

- * 2 - 5 days post donation
- * either whole blood or packed cells
- * contains \approx 13% citrate as anticoagulant (CPD or ADC)

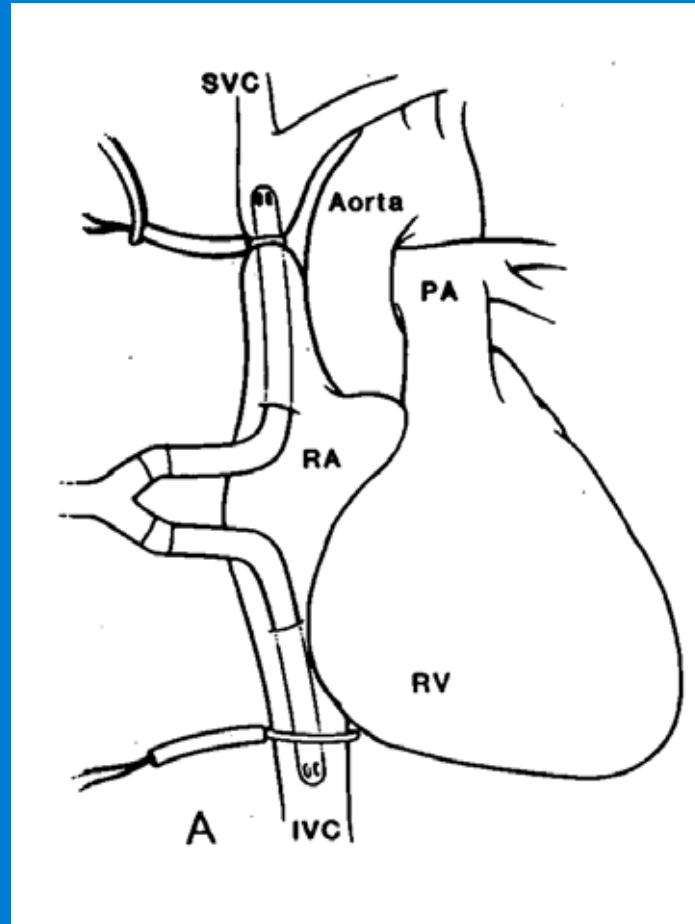
In practice:

- * must be buffered with NaHCO_3
- * \therefore must use water to \downarrow $[\text{Na}^+]$
- * use 1 unit + crystalloid (+ albumin) + water if required.
- * patients 6 kg - 15 kg
- * prime volume 500 - 1100 mls

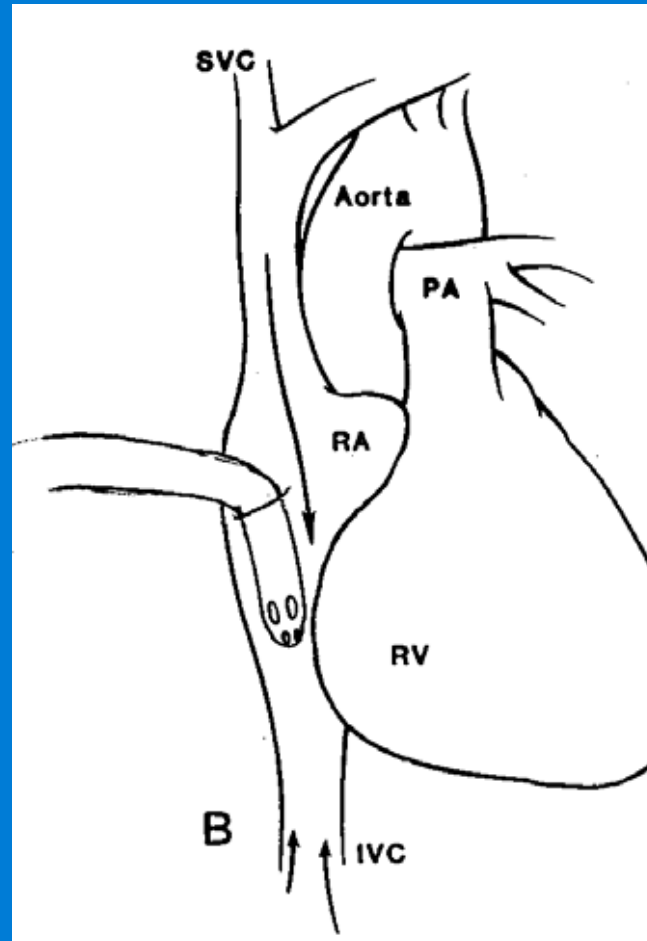
Bloodless (Clear) Prime

- * Dilution up to 40 ml/kg
 - * Crystalloid = Haemaccel or 4% Albumin
 - * Contains Heparin
 - * For patients > 15 kg (with adequate Hb) may be used for smaller patients with high Hb.
 - * Blood remaining in the circuit at the end of surgery is reinfused.
 - * prime volume 500 - 1600 mls

Bicaval Cannulation



Atrial Cannulation



At Initiation of Bypass.....

* Abrupt reduction in haematocrit & protein leads to:

↓ Viscosity

↓ Systemic Venous Resistance (SVR)

∴ ↓ Blood pressure

Reflex ↑ in catecholamine release

At Initiation of Bypass.....

Right and Left atrial pressures \rightarrow 0 mmHg
which leads to:

\uparrow ADH and aldosterone

\rightarrow \downarrow Urine output

And \rightarrow ? Inadequate blood volume

Reflex \uparrow in catecholamine release

At Initiation of Bypass.....

Flow < previously which leads to:

↓ Haematocrit

↓ Pulsatility

↓ Blood Pressure

∴ ↓ Systemic oxygen delivery

Reflex ↑ in catecholamine release

At Initiation of Bypass.....

Blood is exposed to foreign surfaces, etc.
this leads to:

- * ↑ complement activation
- * ↑ platelet release reaction
- * ↑ leucocyte activation
- * ↑ fibrinolysis
- * ↑ kininogen byproducts
- * ↑ coagulation

Increased Complement Activation

- Via alternate pathway → C3a
 - Also caused by Protamine
 - C5 attaches to neutrophils (sequestered in lungs)
 - General ↓ in serum complement concentration
 - Greatly ↑ risk of infection
 - Greatly enhanced inflammatory response

Leucocytosis

- The “defence” against “invasion”
- An integral part of the inflammatory response
- Activation and subsequent adhesion occurs
- ∴ sequestration (especially in pulmonary tree)
- Oxygen free-radical & leucotriene production
- ↓ Phagocytic activity
- ↑ Elastase & myeloperoxidase production
- ∴ Tissue damage & ↑ risk of infection

Kininogen By-products

- Bradykinin & Kinin are both inflammatory
- ↑ Vascular permeability
- ↓ SVR
both directly & by cytokine production
- Activation of leucocytes → sequestration

Adequate/Optimal Perfusion

Dilated, well perfused, not shut down,
warm, not acidotic, not water loaded,
urine producing, non bleeding patients.

Adequate/Optimal Perfusion

Use vasodilators when appropriate.

Use vasoconstrictors when appropriate.

Avoid hypotensive pathophysiology

- * substantial haemorrhage, rapid ↓ in Hct
- * rapid loss of pulsatility, rapid transfusion
- * low flow

Maintain high flows

- * ≥ 150 ml/kg/min
- * ≥ 2.4 l/m²/min

Moderate blood pressures

- * not too low, not too high

Elective Cardiac Arrest & Cardioplegia

During cardiac surgery utilising CPB if a procedure involves:

intra-cardiac anatomy or,

there is communication between the left and right sides of the heart or,

the procedure involves the ascending aorta,

the aorta is cross-clamped and the heart arrested.

The only organ not receiving a blood supply is the heart.

Elective Cardiac Arrest & Cardioplegia

Physiological requirements

- * Still, relaxed myocardium.
- * Protection of myocardium throughout the ischaemic (arrest) period.
- * Prompt resumption of effective cardiac activity and rhythm.

Cardioplegia requirements

- * Prompt & complete cessation of electromechanical activity
- * Preservation & protection
- * Normalised myocardial function after the aortic cross-clamp is removed.

Elective Cardiac Arrest & Cardioplegia

Myocardial Protection:

- * K^+ induced arrest and asystole using cardioplegia solution (CPS).
- * Hypothermia induced by CPS and cold Ringers solution applied topically.
- * Maintained by regular application and use of Ringers slush around the myocardium.

Cardioplegia Solution

Cardioplegia solution generally contains:

- * K^+
- * HCO_3^-
- * Ca^{2+}
- * Glucose

CPS can be crystalloid, colloid or blood based. They can be delivered at a variety of temperatures and pressures dependent upon the patient and procedure.

Cardioplegia Solution

Blood Cardioplegia Base Solution (500 ml)

Sodium – 77 mmol

Potassium – 40 mmol

Magnesium – 15 mmol

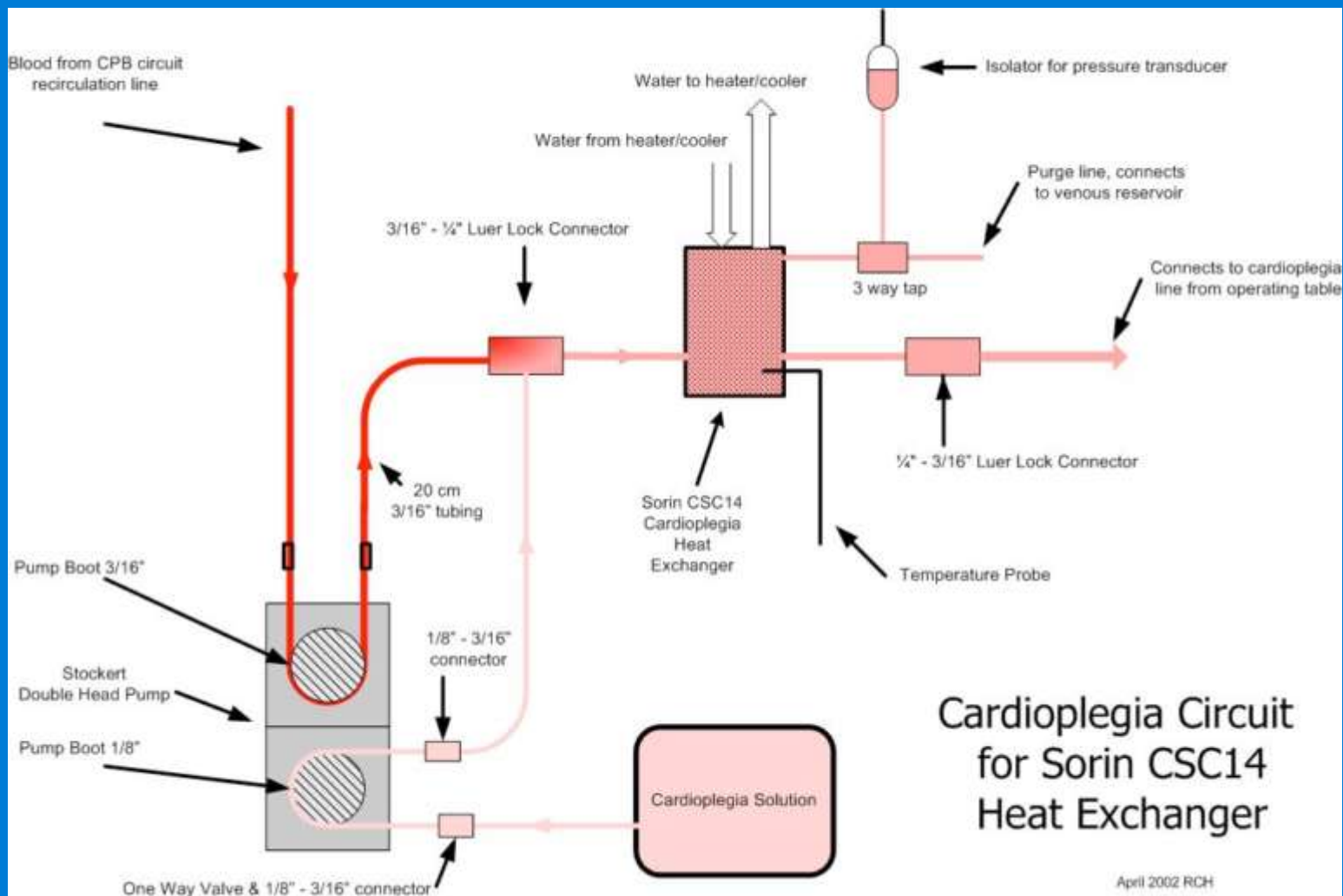
Chloride – 149 mmol

Glucose – 11 mmol

Lidocaine – 1 mmol

To this is added 25 ml of 8.4% Sodium Bicarbonate and 28 mmol of Monosodium L-Aspartate. The induction dose is mixed in a ratio of 1:4, Base solution: blood. The maintenance dose is delivered at 1:6, Base solution: blood.

Cardioplegia Circuit



Circulatory Arrest

Used primarily when the surgeon's field of vision is compromised or there is a major procedure involving the aortic arch. Now isolated cerebral perfusion is usually used.

The patients are generally neonates ($< 3\text{kg}$).

It is always performed under some degree of hypothermia.

The period of circulatory arrest is limited by the degree of hypothermia.

Circulatory Arrest

In practice:

The patient is cooled on CPB to the appropriate temperature.

<u>Temperature</u>	<u>Safe period without circulation</u>
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<18° C.	45 minutes
22° C.	30 minutes
28° C.	13 minutes
30° C.	5 minutes

Kirklin & Barret-Boyes; Ch 2.

The use of steroids stabilises cell membranes and limits end organ oedema.

Weaning from Bypass

While on full support via venous occlusion start volume loading

Ventilating

$Ra > 5 \text{ mmHg}$

$LA > 4 \text{ mmHg}$

$PA < 1/2 \text{ systemic pressure}$

Volume Requirements after CPB

Maintain adequate pressures.

Maintain or improve haematocrit

Control bleeding using appropriate fluids/drug combinations.

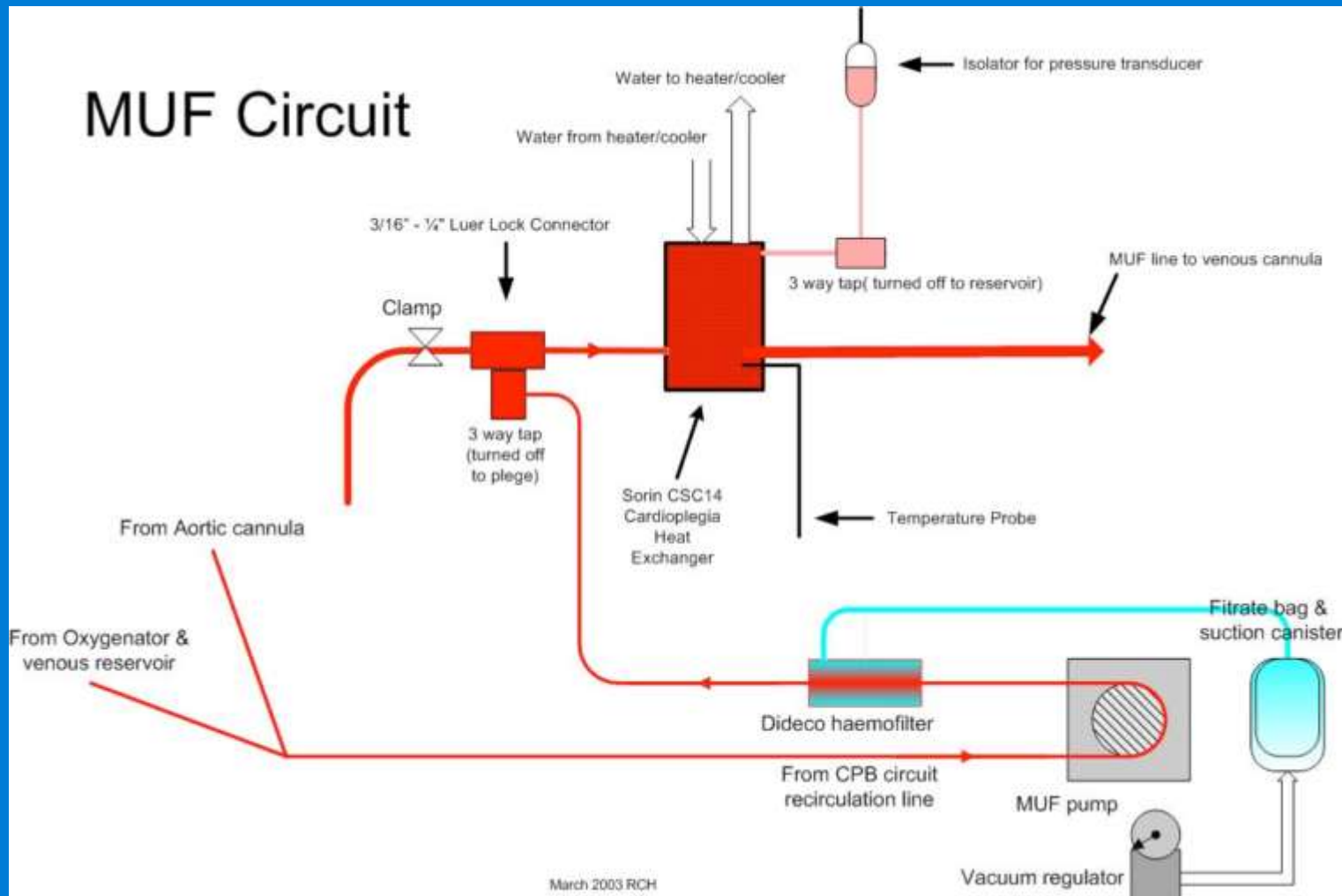
Modified Ultrafiltration (MUF)

The increase in extravascular fluid which tends to accompany cardiopulmonary bypass (CPB), is in part due to increased capillary permeability, as a result of the inflammatory response initiated by CPB.

Perioperative ultrafiltration and more specifically post CPB modified ultrafiltration (MUF), can be used to decrease total body water thereby minimising these deleterious effects

Our aim is to remove 100ml/kg of filtrate and this usually requires a period of 12 to 20 minutes in the neonatal population. Time taken and amount of filtrate removed will vary in larger children.

Modified Ultrafiltration (MUF)



Donor or Pump Blood Post-Op

	Donor blood	Pump blood	
Hb ICU 1 Hr	11.7	10.6	N.S.
Hb ICU 12 Hr	12.2±1.3	11.9±1.6	N.S.
Tot.bld,FFP,Plt	234 ml	242 ml	N.S.
Urine ml/kg/12hr	26.7	22.2	N.S.
Tot Heparin mg/kg	7.2	7.3	N.S.
Tot Protamine mg/kg	4.5	4.4	N.S.
ICU hours	36.4±33.6	26.9±13.8	N.S.
Post-op hosp days	9.5±3.8	11.6±6.7	N.S.

“Undesirable” Features of CPB

- Haematology / Haemostasis
- Use of suction
- Blood contact with CPB circuit
- Perfusion imbalances
- Haemodilution
- Prolonged cross-clamp times
- Use of relatively large amounts of donor blood and blood products
- Emboli

Complications of CPB

- Sleep deprivation.
- Potential for exposure to communicable diseases
- Terrible “bad hair” days
- Pale skin
- Forced association with staff of debatable character
- Your children wonder who you are
- Moderate levels of stress, sometimes very high levels
- ECMO and VAD
- Requirement to lecture