The Cardiopulmonary Bypass Circuit

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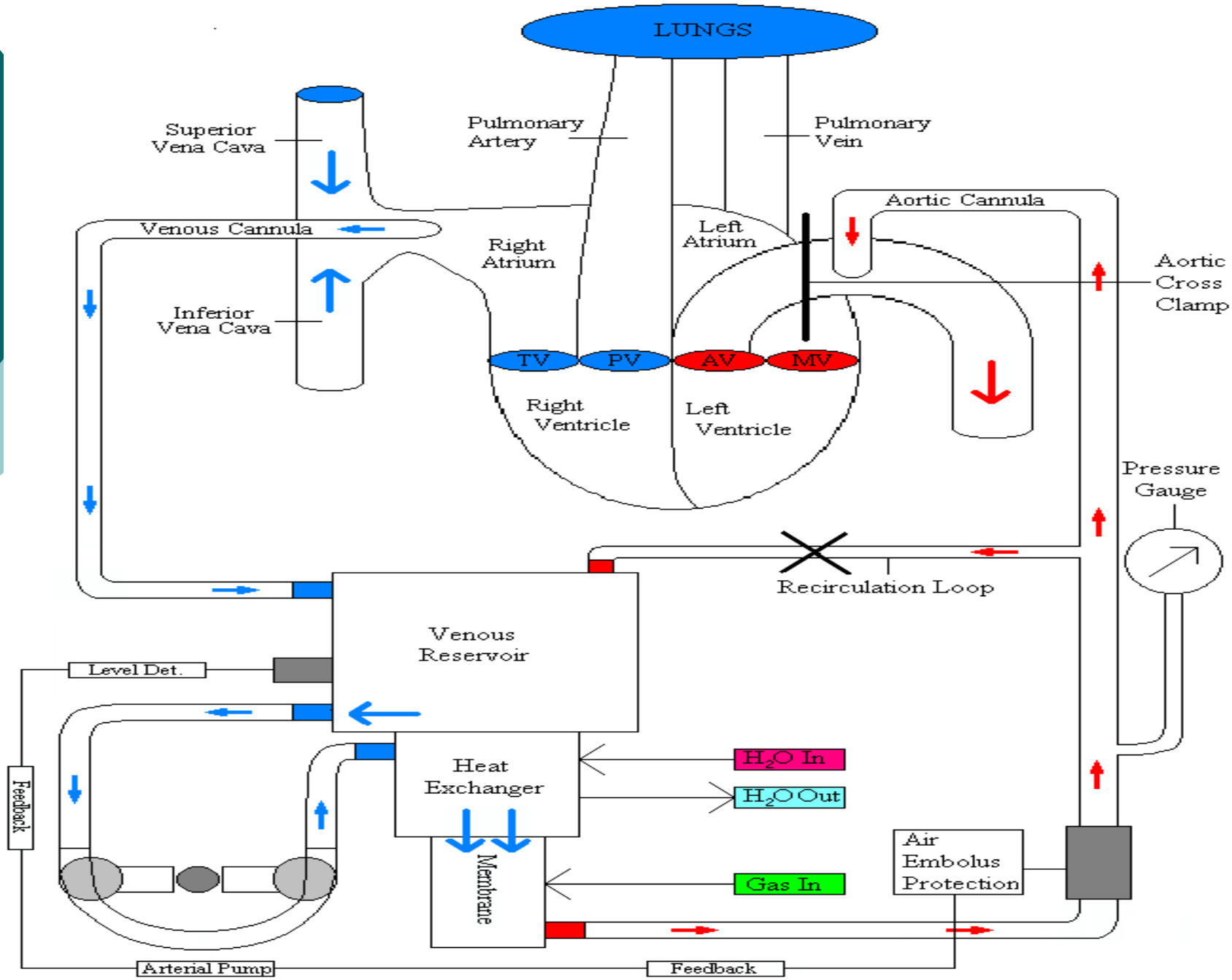

LUNGS
Superior Vena Cava
Pulmonary Artery
Pulmonary Vein
Aortic Cannula
Venous Cannula
Left Atrium
Right Atrium
Aortic Cross Clamp
Inferior Vena Cava
TV
PV
AV
MV
Right Ventricle
Left Ventricle
Pressure Gauge
Recirculation Loop
Venous Reservoir
Level Det.
Heat Exchanger
H_2O In
H_2O Out
Feedback
Membrane
Air Embolus Protection
Gas In
Arterial Pump
Feedback

Venous Cannulation

- Cannulation RA / IVC
- Bicaval SVC & IVC
- Femoral venous access for IVC + direct SVC cannulation
- Femoral venous access for bicaval cannulation
- Wire reinforced to prevent kinking

Venous Line

- Can vary in diameter size – Adult ½”
- PVC
- Passive drainage – siphon – air lock?
- Reservoir is lower than patient
- Contains SVo2 & Hct sensor
- Vacuum Assisted Venous Drainage
- VAVD -100mmHg maximum negative pressure

Venous reservoir

- Hard-shell Polycarbonate
- Vary in volume capacity- Adult 4000mls
- Must be vented – positive pressure relief valve
- Venous filter – polyester screen 47 microns
- Cardiotomy – polyester depth filter
- Defoamer – polyurethane foam
- Multiple ports – multiple sizes
- Drugs administered into reservoir via small A-V shunt.

The Roller Pump

- Double headed roller pump - propels the blood.
- Pump head occlusive – independent of resistance.
- Pump calibration - pump boot size & rpm relative to flow rate
- ½” pump boot 100 rpm = 4.5 L/Min
- 3/8” pump boot 100 rpm = 2.8 L/min
- Silicone – pliable at low temperatures
- PVC – brittle at low temp , tubing spallation & motor wear.
- Centrifugal pump – vortex / kinetic energy. Produces less haemolysis. Are used for prolonged cases e.g. Aortic Dissection. Non occlusive, resistance has an effect on flow.
- Patient flow rate = BSA M^2 x 2.4 L/Min/M^2

The heat exchanger

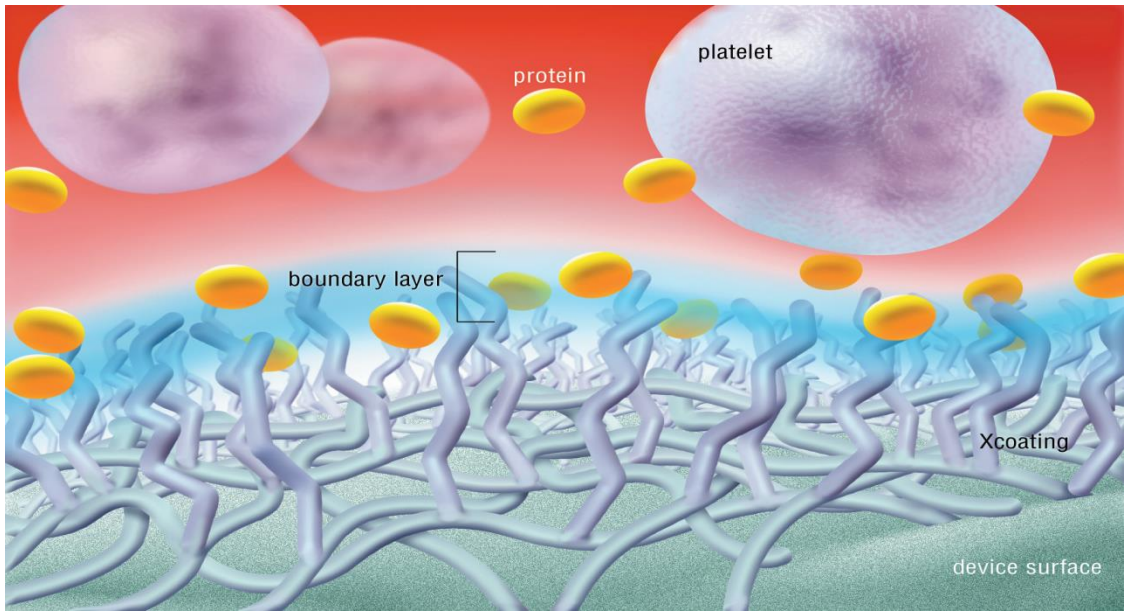
- Stainless steel – good thermal conductivity
- 0.2 M^2 surface area
- Water / Blood counter or cross current flow for greater efficiency
- Positioned before oxygenator to reduce GME as lower O_2 tension present (venous blood)
- H2O circulated at 15 L/min
- H2O temperature range 8^{o}C to 38^{o}C (rarely above 37.5)
- Blood to water temperature gradients 10^{o}C when cooling & 5^{o}C during rewarming

The oxygenator

- Polycarbonate housing
- Microporous polypropylene hollow fibre
- Various gas transfer surface areas – 2.5 M^2
- Low priming volume – 240mls (including heat exchanger)
- Rated up to 7 L / min flow – 6’8” & 160 kg
- Designed for low pressure drop
- Maximum blood inlet pressure 1000mmHg
- Purged for easy priming / repriming

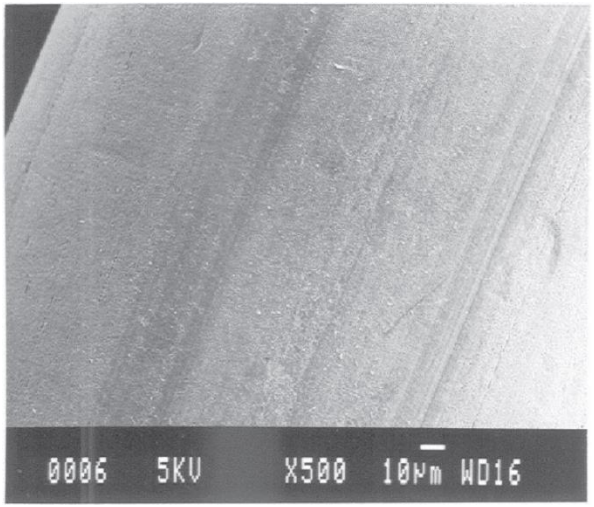
The oxygenator

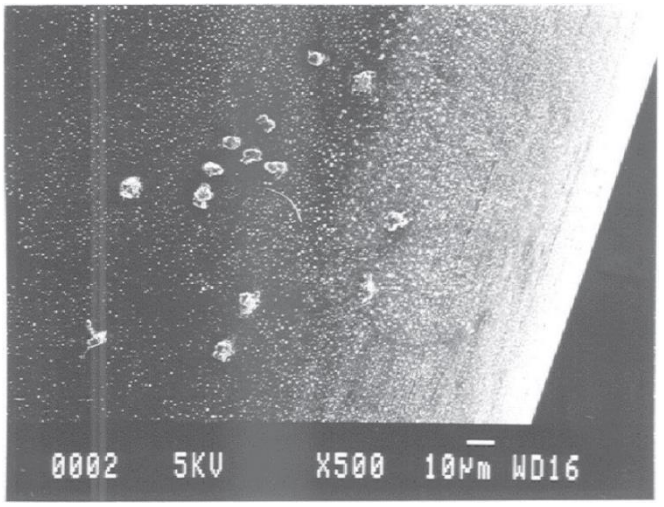
- Bio passive amphiphilic surface coating reduces protein denaturation & platelet adhesion.
- The surface coating creates a boundary layer, composed of water molecules and the patient's native proteins.



The oxygenator

- The proteins do not deform or become denatured in the boundary layer, so platelets do not aggregate or adhere to the surface
- Fibre surfaces, one with surface coating (left) and one uncoated (right), shown after four hours of ex vivo recirculation with porcine blood. The uncoated surface shows emboli aggregation





The Arterial Filter

- 32 micron screen filter surrounding the fibre bundle
- Removes microemboli including gas emboli, fat emboli & aggregates composed of platelets, red blood cells other debris.
- Designed as bubble trap – top to bottom flow.
- Constantly purged – Added protection against gross air embolus
- Pre & post pressure monitored continuously for increased resistance – low ACT / thrombus formation?

Arterial Cannula

- Various sizes & designs
- Straight 24 Fr (8mm) Aortic
- 17Fr or 18 Fr (6mm) Femoral Artery
- Smallest diameter in the circuit
- Fr = outside diameter. Better quality cannula have a lower pressure drop as they maximise inner diameter by reducing wall thickness.
- Factors influencing mechanical haemolysis are turbulence, flow velocity & jet injection (loss of velocity between two fluid systems)

Safety

- Reservoir low level alarm – minimum 250mls
- Oxygenator designed as bubble trap (top to bottom flow)
- Arterial filter constantly purged
- Ultrasonic bubble detector <4mm
- Oximeter in gas line – Fio2 accurate
- ACT > 400 seconds on CPB- continuously monitored
- Circuit Pressure monitoring

Safety - In line blood gas analyser

- Measures arterial pH, PO_2, PCO_2, K+, BE
- Measures venous oxygen saturation
- Measures Hb & Hct
- Updates every 5 seconds
- Arterial sensor connected via AV shunt
- Venous sensor in venous line
- Calibrated against blood gas analyser
- Helps to identify trends early e.g. falling PO_2, SVO_2, increasing PCO_2

Myocardial Protection

- K+ induced Diastolic arrest – stops electromechanical activity. Low ventricular end diastolic wall tension.
- Significantly reduces myocardial oxygen consumption.
- Hypothermia further reduces oxygen consumption
- Aerobic metabolism with oxygenated cardioplegia
- Maintain arrest with re-administration every 20 minutes
- Antegrade & Retrograde (30mmHg) delivery possible.

Single Pass Blood Cardioplegia Circuit

- Dual Head roller pump system
- Arterial Blood from Oxygenator port
- High Strength Cardioplegia solution
- Ratio of blood to cardioplegia pumps determines cardioplegia concentration
- Heat exchanger – cold 12^{o}C or warm 34^{o}C
- Bubble trap – hydrophobic filter
- Pressure monitoring – high pressure alarm
- Maximum flow rate 500 mls/min

Blood Cardioplegia

- Benefits
- Reduced systemic haemodilution with repeated administration compared to crystalloid cardioplegia.
- Blood helps maintain oncotic pressure
- Blood contains natural buffers
- Blood is a free radical scavenger
- Blood can transport & deliver oxygen, remove carbon dioxide.

Q & A

- Thank you