SNS COLLEGE OF ALLIED HEALTH SCIENCES

SNS Kalvi Nagar, Coimbatore - 35

Affiliated to Dr MGR Medical University, Chennai

DEPARTMENT OF CARDIO PULMONARY PERFUSION CARE TECHNOLOGY

COURSE NAME : PRINCIPLES OF PERFUSION TECHNOLOGY I

TOPIC : HEAT EXCHANGERS

YEAR: II nd YEAR

HEAT EXCHANGER

- Heat exchangers are the **integral components of all the oxygenators** used for CPB and can be external in oxygenators used for ECLS\ECMO.

- It is the one which incorporates CPB **to maintain body temp**. of patient during bypass.

- The function of the heat exchanger is **to regulate the temperature of the blood perfusing the patient**, which then raises or lowers the body temperature depending on the type of surgical procedure being performed.

- Heat exchangers must be made of **biologically inert materials** that reduce the risk for **excessive activation of cellular and non cellular elements of the blood**.

- The heat transfer surface is usually made of **stainless steel, aluminum or glass**.

- The material used should have **good thermal conductivity** and are coated with polymers or other surface modifying agents to minimize blood activation

PRINCIPLE

- The principle behind the heat is way of expressing energy

this exchange of energy occurs either into or out of the blood. It is provided by non sterile water that is circulated through a heater cooler unit.

The patient tended to become cool due to the temperature of their surroundings.

Cont……..

- To maximize heat efficiency of heat transfer, blood and water pathways flow in a **counter current direction**, which is also reduces outgassing of solutions due to rapid changes in temperature.
- Although increasing heat exchanger surface area results in a greater heat transfer, it requires larger prime volume and more severe hemodilution.
- Heat exchangers are designed to add or remove heat from the blood, thereby controlling the patient's body temperature.
- During its flow through ECC circuit, the blood cools and hence heat must be added to avoid patient cooling .
- In addition the patient temperature is deliberately lowered and then restored to normothermia before discontinuing CPB

TYPES OF HEAT EXCHANGERS

- There are three primary classifications of heat exchangers according to their flow arrangement

- PARALLEL FLOW HEAT EXCHANGER
- COUNTER FLOW HEAT EXCHANGER
- ACROSS FLOW HEAT EXCHANGER

- In *parallel - flow* heat exchanger

the two **fluids enter the exchanger at the same end**, and travel in parallel to one another to the other side

- In *counter-flow* heat exchangers

the **fluids enter the exchanger from opposite ends**. The counter current design is the most efficient, in that it can transfer the most heat from the heat (transfer) medium per unit mass due to the fact that the average temperature difference along any unit length is *higher*.

- In a*cross-flow* heat exchanger,

the **fluids travel roughly perpendicular** to one another through the exchange

Constraints on rate of heat transfer

- The temperature difference between the circulating water from the heater –cooler and the blood determines HEAT TRANSFER
- A thermal boundary layer exists in the blood flowing just beside the wall of heat exchanger – wall seperating blood & water
- The exact temp. profile in the boundary layers depends on the nature of velocity of fluid movement.
- Changing temp. alters the solubility of gases within the solution, & higher partial pressures of gas increase the rate of out gassing the solution.
- Due to the potential for gas emboli from outgassing - maintenance of max. of a 10°c is suggested b/w waterside & blood side.

- It is seen that using reduced temperature gradient(<6) & longer rewarming times to improve neurocognitive outcomes in patients undergoing CABG with CPB
- Blood damage in the form of protein denaturation limits the absolute max. temp.that can be safely achieved in the blood.

HEAT TRANSFER

- Heat exchanger function is described as heat transfer coefficient

- Heat transfer coefficient =

  inlet blood tempt * outlet blood tempt.

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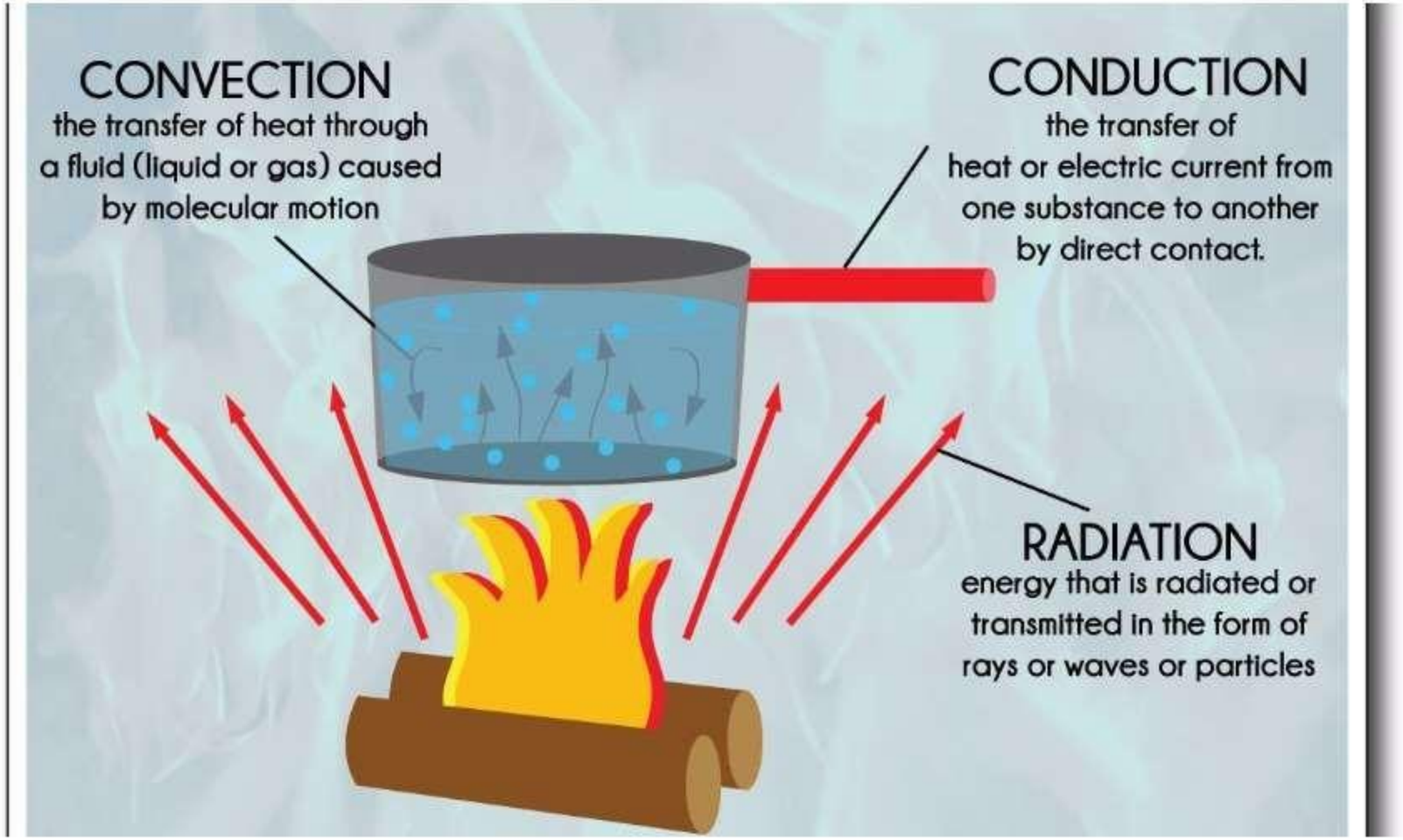
  inlet water tempt. * outlet water tempt.

- **heat transfer is possible by 3 ways**

  - *conduction [through solids]*
  - *convection [from liquid to solid]*
  - *Radiation*


CONVECTION
the transfer of heat through a fluid (liquid or gas) caused by molecular motion
CONDUCTION
the transfer of heat or electric current from one substance to another by direct contact.
RADIATION
energy that is radiated or transmitted in the form of rays or waves or particles

- Within CPB the major forms of heat transfer in heat exchanger is - **conduction & convection.**

- Presently used heat exchanger consists of supply of a **coiled tubing**.

- “Heat exchange” is also enhanced in most device by flowing the blood & water in **opposite direction**.

Rate of cooling & rewarming

- During TCAs the total perfusion time has been lengthened because of the time required to cool & stabilize the patient @ desired temperature & then the prolonged rewarming from the desired hypothermic temperature.

- ***The temp. difference circulating water & blood drives heat transfer.***

- Rapid cooling is commonly used at the onset of CPB where the circulating water is cooled to temp. approaching zero temp, but @ conclusion rate of rewarming is limited.

- The rewarming rate will be slower than the rate of cooling, since the rewarming water bath temp. should never exceed 42 degree c .
- Consequences @ above 43°C
- Thermal injury
- Destruction of blood formed elements.
- As the patient is rewarmed; the gradient between the blood & water becomes smaller ; - the rate of rewarming becomes slower.

- **Rapid rewarming causes**

blood damage

bubble formation

cerebral injury

blood damage may occurs in the form of protein denaturation

The risk of microbubble embolization can be reduced by;

- *maintaining a temp. gradient between water & patient……*
- **less than 10 to 12 °C in adults**
- **less than 6 to 8°C in pediatrics**
- *limiting arterial partial pressure of oxygen to below 200mmHg.*

Cont……

Rapid cooling causes intravascular aggregation

No intravascular aggregation has been observed at cooling rate less than 1 degree Celsius per minute.

The rewarming rate should be limited to a 1 degree Celsius temperature rise in 3 to 5 minutes……..

Cases when heat exchange is preferred

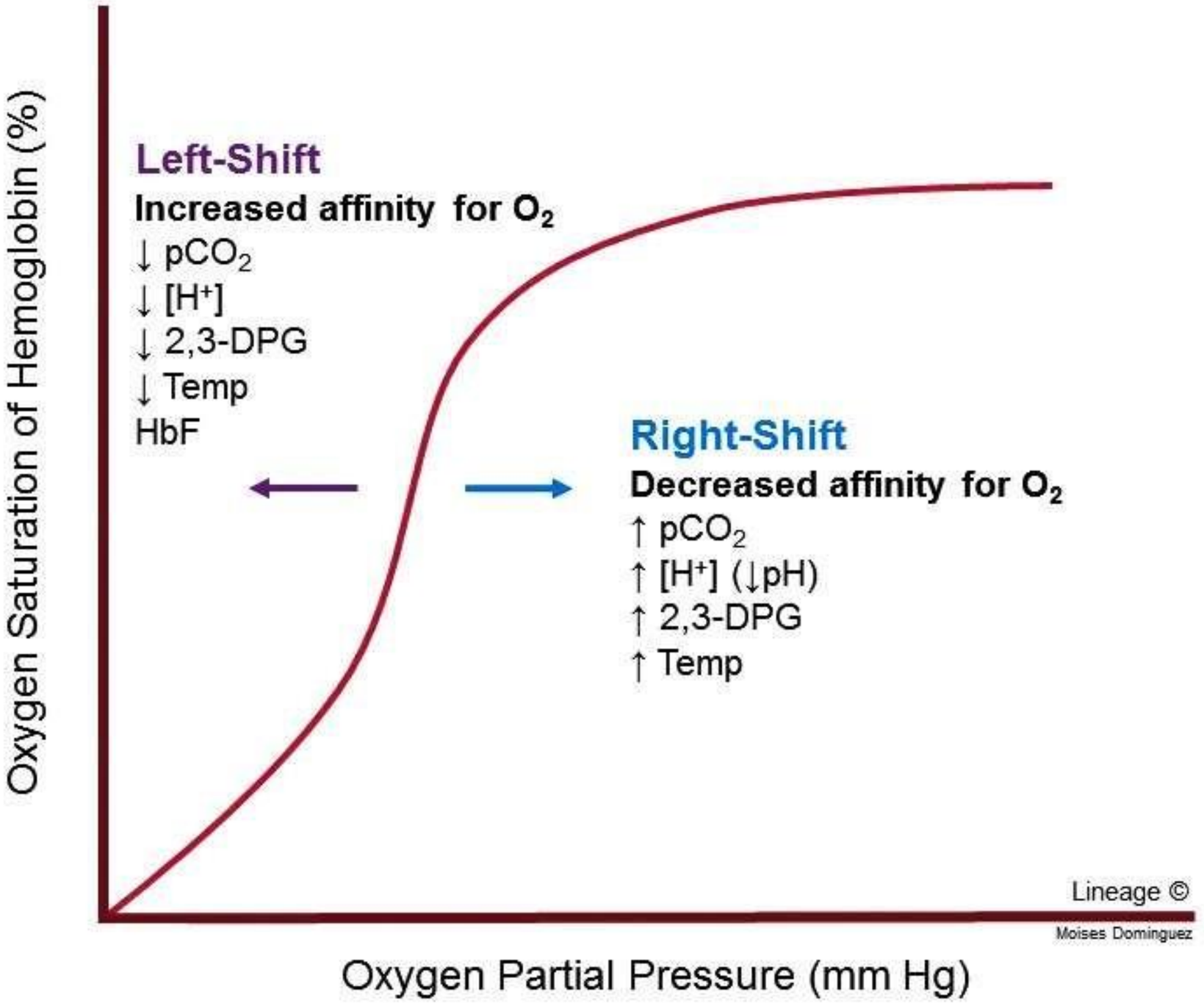
- It decreases the rise of microemboli formation.
- It uses the oxygenator as bubble trap

If the heat exchangers are not transparent ;
The perfusionist would be unable to see the blood &the presence of the bubbles

The most limiting factor in oxygen – Hb dissociation curve:

- When the temp. is low, the solubility of the gases are high & when it reaches the heat exchanger, the blood is exposed to warm temp.
- Here, when the temp. increases - decreases solubility- causes microbubbles of the gas to come out of the solution
- This is a disadvantage in rapid cooling & rewarming

Oxygen-Hemoglobin Dissociation Curve



Cont……

- **The driving temperature across the heat transfer surface varies with position, but an appropriate mean temperature can be defined.**

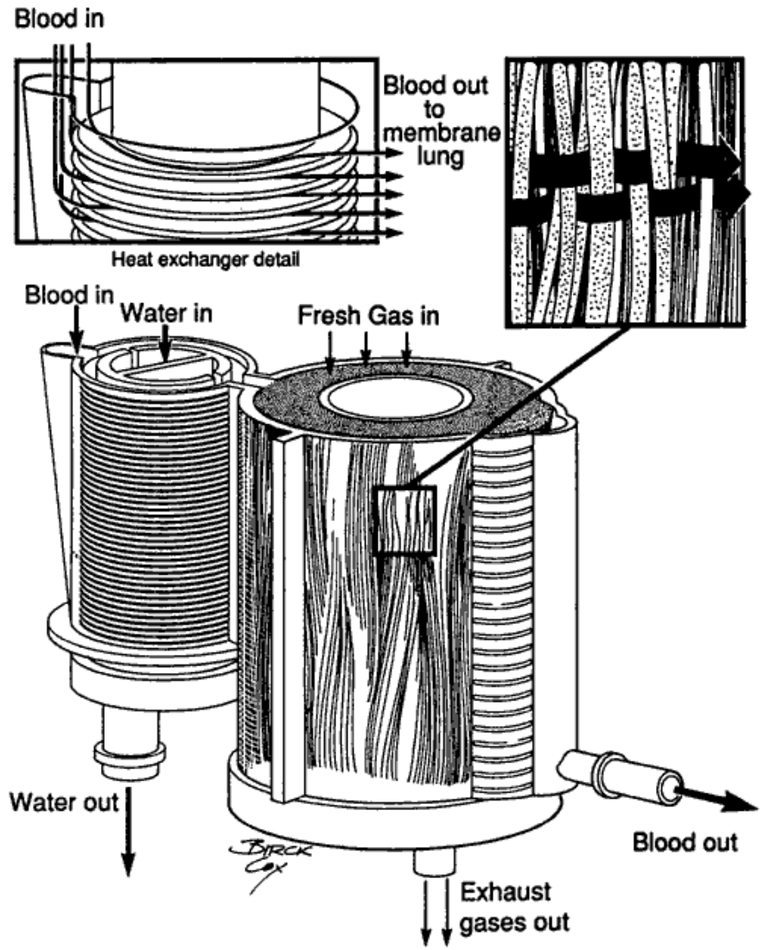
- Transfer of the heat energy occurs by the circulation of water from the ***heater and cooler unit***, which is the part of CPB equipment

HEATER COOLER UNIT

Cont……..

- Although separate heat exchangers were used in ECCs in the past , currently they are invariably included as an integral part of the disposable oxygenator.
- Heat exchangers are located **proximal to the gas exchanging section** of the circuit to **minimize the risk of releasing micro bubbles of gas from the blood**, which could occur if the blood is warmed after being saturated with gas .
- An additional risk of heat exchangers is water leakage into the blood path. although this incident is rare, when it occurs it is most often manifested by the appearance of hemolysis and elevated serum potassium

HEAT EXCHANGER



- A source of hot and cold water, a regulator/blender, and temperature sensors are supplemental requirements of heat exchangers.
- Although hospital water may supply such a source, a sand alone water cooler and heater is used more often.
- Malfunction of these coolers-heaters is one of the more common incidents during CPB.
- Separate heat exchangers are needed for administration of cardioplegic solution and /or blood for coronary perfusion.

- For efficiency, heat exchangers are designed to **maximize the surface area of the wall between the two fluids**, while minimizing resistance to fluid flow through the exchanger.
- The exchanger's performance can also be affected by the addition of fins or corrugations in one or both directions, which increase surface area and may channel fluid flow or induce turbulence.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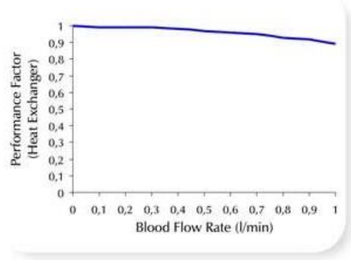
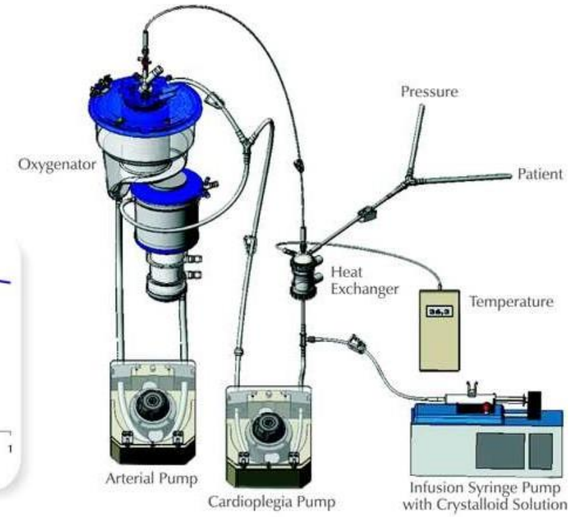
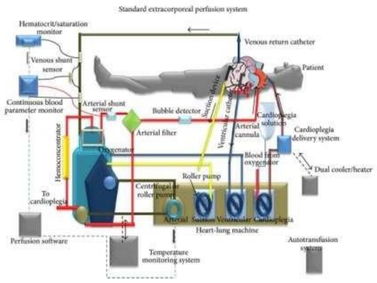
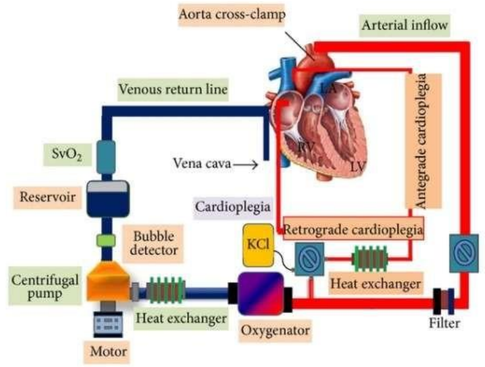
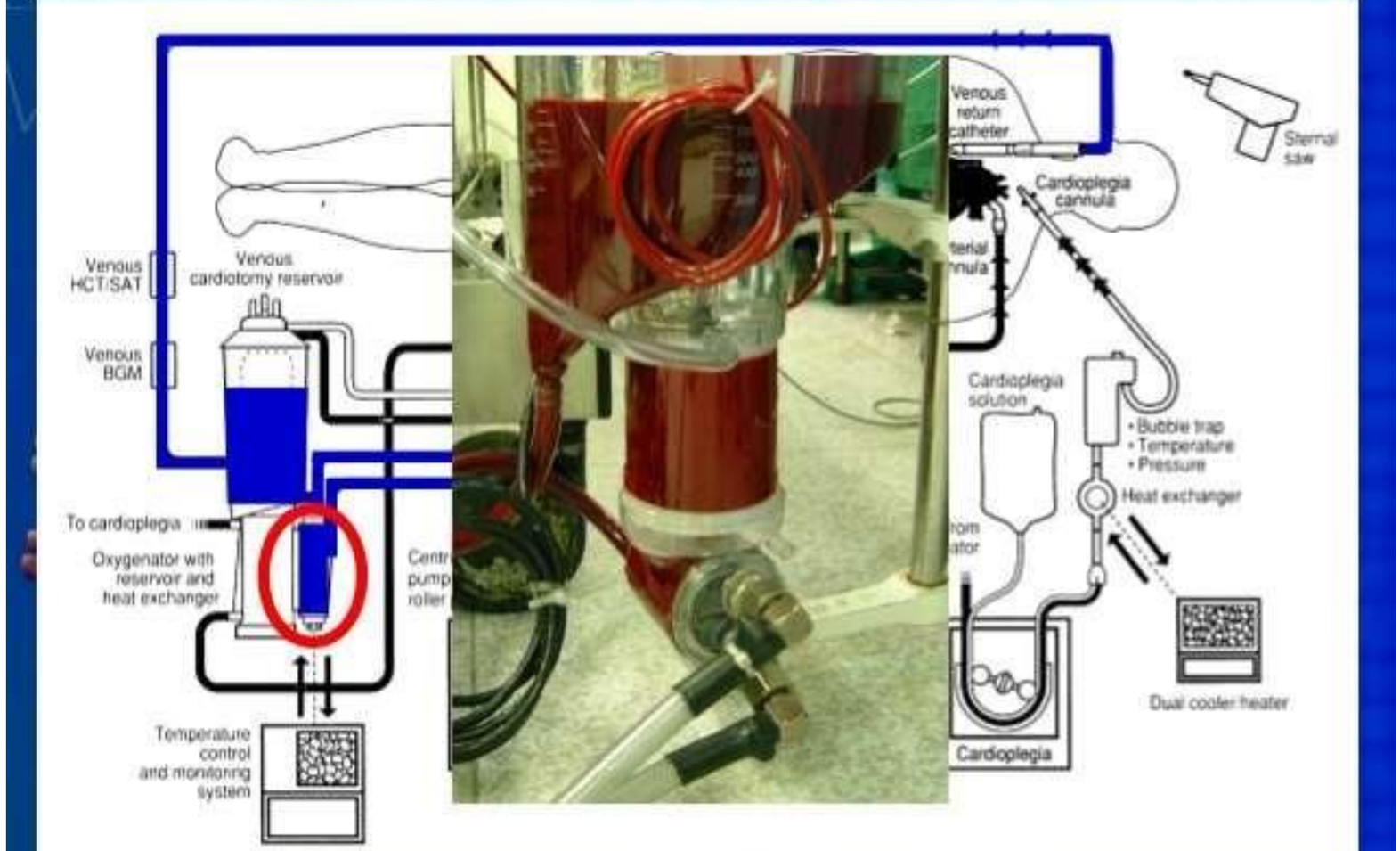

Performance Factor (Heat Exchanger)
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 1
Blood Flow Rate (l/min)


Oxygenator
Pressure
Patient
Heat Exchanger
Temperature
Arterial Pump
Cardioplegia Pump
Infusion Syringe Pump with Crystalloid Solution


Standard extracorporeal perfusion system
Hematocrit/saturation monitor
Venous shunt sensor
Continuous blood parameter monitor
Arterial shunt sensor
Bubble detector
Venous return catheter
Patient
Arterial filter
Cardioplegia solution
Arterial cannula
Cardioplegia delivery system
Oxygenator
Blood heat exchanger
Dual cooler/heater
Roller pump
Hemoconcentrator
To cardioplegia
Centrifugal roller pump
Arterial
Venous
Cardioplegia
Heart-lung machine
Perfusion software
Temperature monitoring system
Autotransfusion system


Aorta cross-clamp
Arterial inflow
Venous return line
Antegrade cardioplegia
RV
LV
SvO2
Vena cava
Reservoir
Cardioplegia
Retrograde cardioplegia
Bubble detector
KCl
Centrifugal pump
Heat exchanger
Heat exchanger
Oxygenator
Filter
Motor

Heat Exchanger



SIGNIFICANCE……

- Heat exchangers are necessary to **maintain the temperature of blood returning to the patient within a limited physiologic range** and are particularly important in the **management of neonatal patients** due to their propensity for heat loss and inefficient thermoregulatory ability.
- To prevent unnecessary heat loss, the heat exchanger is generally placed distally in the circuit just to warm the blood as it being returned to the patient.
- A series of silicone coated, non-permeable stainless steal tubes allow warm water to flow in a countercurrent manner to blood flowing through **ECMO circuit**
- Blood is heated as it flows from higher to more dependent portion of the vertically oriented heat exchange unit, permitting air bubbles to be tapped in the upper section.

- Failure of heat exchanger occurs in approximately 1% to 2% of ECMO cases.-

  most commonly due to the leakage of water from the device's inflow and outflow connectors.

- Leakage of blood within the heat exchanger is uncommon, as is leakage of water into the blood phase of the unit because of the differential fluid pressures within ECMO circuit.